



W. G. FARLOW

## HARVARD BOTANI

At a meeting of the Botanical Department held Oct. 20, 1903, the following vote was passed:

"Under the head of *Harvard Botanical Memoirs* it is proposed to include all quarto publications issuing from the Gray Herbarium, the Cryptogamic Herbarium, and the Botanical Laboratories of Harvard University, including theses presented for the degrees of Ph.D. and S.D. in Botany. Inasmuch as some of the future publications are likely to be continuations of subjects treated in quarto papers already published, it seemed desirable to begin the numbering of the *Memoirs* with the year 1880, the date of the first quarto publication of any member of the botanical staff at present connected with Harvard University."

At a meeting on Nov. 25, 1916, it was voted to discontinue the series of *Botanical Memoirs*. In all, nine numbers have been issued, the titles of which are given below.

- I. The Gymnosporangia or Cedar-Apples of the United States.  
By W. G. Farlow. *Anniversary Memoirs, Boston Soc. Nat. Hist.* 1880. Pp. 38. Pls. 1 and 2.
- II. The Entomophoreae of the United States. By Roland Thaxter. *Mem. Boston Soc. Nat. Hist.*, IV, No. 6. Pp. 133-201. Pls. 14-21. April, 1888.
- III. The Flora of the Kurile Islands. By K. Miyabe. *Mem. Boston Soc. Nat. Hist.*, IV, No. 7. Pp. 203-275. Pl. 22. Feb. 1890.
- IV. A North American Anthurus: its Structure and Development.  
By Edward A. Burt. *Mem. Boston Soc. Nat. Hist.*, III, No. 14. Pp. 487-505. Pls. 49 and 50. Oct. 1894.
- V. Contribution towards a Monograph of the Laboulbeniaceae.  
By Roland Thaxter. *Mem. American Acad. of Arts and Sci.* Boston. XII, No. 3. Pp. 189-429. Pls. 1-26. Presented May 8, 1895. Issued Oct. 14, 1896.
- VI. The Development, Structure, and Affinities of the Genus Equisetum. By Edward C. Jeffrey. *Mem. Boston Soc. Nat. Hist.*, V, No. 5. Pp. 155-190. Pls. 26-30. April, 1899.
- VII. Comparative Anatomy and Phylogeny of the Coniferales, Part I. The Genus Sequoia. By Edward C. Jeffrey. *Mem. Boston Soc. Nat. Hist.*, V, No. 10. Pp. 441-459. Pls. 68-71. Nov. 1903.
- VIII. The Comparative Anatomy and Phylogeny of the Coniferales, Part II. The Abietineae. By Edward C. Jeffrey. *Mem. Boston Soc. Nat. Hist.*, VI, No. 1. Pp. 1-37. Pls. 1-7. Jan. 1905.
- IX. Contributions towards a Monograph of the Laboulbeniaceae, Part II. By Roland Thaxter. *Mem. American Acad. of Arts and Sci.*, XIII, No. 6. Pp. 219-469. Pls. 28-71. June, 1908.

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## HARVARD BOTANICAL MEMOIRS

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This set of Menairs found February  
1917, is the authentic set which  
belongs to the Botanical Department.  
W. G. Farlow. March 17. 1917.





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W. G. Farlow

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FROM THE ANNIVERSARY MEMOIRS OF THE BOSTON SOCIETY OF NATURAL HISTORY

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THE GYMNOSPORANGIA OR CEDAR-APPLES  
OF THE UNITED STATES.

B. W. G. FARLOW.

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BOSTON:  
PUBLISHED BY THE SOCIETY.  
1880.

2/2  
Owing to the absence of the writer during the printing of the accompanying article a considerable part of the proof could not be submitted to him for revision.

#### ERRATA.

Page 3, note 2, for *Ustitaginées* read *Ustilaginées*.

- “ 4, 5th line from bottom, for *colour* read *color*.
- “ 6, 9th “ “ top, for *Euromyces* read *Euuromyces*.
- “ 7, 18th “ “ “ *hymeniferus* read *hymeniferous*.
- “ 9, 5th “ “ bottom, for *varies* read *vary*.
- “ 10, 20th “ “ “ *excresence* read *excrescence*.
- “ 11, 4th “ “ top, for *Berke* read *Berk*.
- “ 12, 10th “ “ “ *fig 17* read *fig. 16*.
- “ 16, 10th “ “ “ *Ths* read *This*.
- “ 18, 12th “ “ “ *Gasperrini* read *Gasparrini*.
- “ 20, 6th & 10th lines from top, for *thuyoides* read *thyoides*.
- “ 21, 7th line from top, for *gymnosporangium* read *Gymnosporangium*.
- “ 22, 9th line from top, for *re-agents* read *reagents*.
- “ 24, 13th “ “ “ *luminata* read *luminatum*.
- “ 31, 10th “ “ “ *tubercles* read *tuberules*.
- “ 31, 23d “ “ “ *pseudoperidis* read *pseudoperidiis*.
- “ 32, 19th “ “ “ before *present* insert *the*.
- “ 33, 9th “ “ “ for *R. lacerta* read *R. lacerata*.

1830. ANNIVERSARY MEMOIRS OF THE BOSTON SOCIETY OF NATURAL HISTORY. 1880.

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## THE GYMNOSPORANGIA OR CEDAR-APPLES OF THE UNITED STATES.

BY W. G. FARLOW.

THE UREDINEAE or rusts include a large number of species which are parasitic on living plants, and, if we adopt the modern view as to their development, they are remarkable for the transformations they undergo, which suggest rather the metamorphoses familiar to us in insects than the ordinary phases of plant life. By earlier writers, the Uredineae were divided into different genera, which were supposed to be distinct, and not genetically connected with one another. Thus, for instance, there were the genera *Puccinia*, *Uredo*, and *Aecidium*, each containing a large number of species. That species of certain genera usually preceded or accompanied species of other genera, as *Puccinia*, was well known, but the two were not supposed to have any genetic connection, and the relation between them was regarded as either quite accidental, or else cases of parasitism.

In 1848 Gasparrini<sup>1</sup> observed the mode of germination of the spores in *Podisoma*, a genus closely related to *Puccinia*, and in 1854, Tulasne<sup>2</sup> extended the observation to the spores of several other genera of Uredineae. He also advanced the opinion that the so-called species of *Uredo*, *Trichobasis*, *Lecythea*, and related genera were merely early stages in the development of species of *Puccinia*, *Phragmidium*, *Melampsora*, etc. In a paper by De Bary,<sup>3</sup> published in 1863, it was maintained that not only were the species of *Uredo* and their allies forms of development of other genera, but that the so-called species of *Aecidium* as well were not distinct, but that they too represented stages of development of *Puccinia*, *Uromyces*, and other genera, and in point of time preceded the stage described by Tulasne as the stylosporic or uredo condition. The papers of Tulasne and De Bary, as might be supposed, gave a fresh interest to the study of the Uredineae and, while previously mycologists had been mainly occupied with describing large numbers of species based on the microscopic character of the spores and the gross appearance of the spots produced in the host-plants, after the appearance of the two papers mentioned it became the fashion to try to ascertain the genetic connection between the different forms known as *Aecidia* and *Uredines* and the different species of *Puccinia*, *Uromyces*, etc. The views of De Bary and Tulasne were, as a general rule, accepted by all the leading mycologists of the continent, but were not so readily received by those of Great Britain. At the present day, the

<sup>1</sup> Osservazioni sulla generazione delle spore nel *Podisoma fuscum*. Rendiconto R. Accad. Scienze Napoli, 1848.

<sup>2</sup> Seconde mémoire sur les Urédinées et les Ustigmatinées. Annales des sciences naturelles. 4 Série. Tome 2.

<sup>3</sup> Recherches sur le développement de quelques champignons parasites. Annales des sciences naturelles. 4 Série. Tome 20.

connection between the uredo forms and other final forms is generally admitted, and the relation of the aecidial stage to the others, as shown by De Bary, is considered to be proved beyond a doubt by nearly all continental mycologists, although there are a few exceptions; but British botanists remain more or less sceptical on the subject.

In consequence of the prevalent view with regard to the development of the Uredineae, writers have ceased retaining such genera as *Uredo* and *Aecidium* except as receptacles for the forms which have not yet been connected with any definite final form, and on the continent a new nomenclature has arisen which has not as yet been adopted by American writers. For the purpose of illustration let us take *Puccinia Graminis*, the common blight on grass which was minutely studied by De Bary.<sup>1</sup> The final form appears as black spots or lines on the leaves and stems of grasses, and is composed of dark colored, rather thick-walled spores, formed of two more or less conical cells united by their bases and attached at the lower end to a mycelium. These two-celled spores are called teleutospores and, in the case of *Puccinia Graminis*, are produced in the autumn. When left to themselves, they germinate the next spring in the following manner. From each cell is given off one, or occasionally two or three, delicate filaments, which scarcely exceed in length the length of the teleutospore. The upper part of the filament becomes somewhat enlarged, and there are generally formed from two to four cross partitions by which the filaments are divided into two to five cells. The upper cells grow out laterally and bear each a small ovoid cell which readily falls from its attachment. The name given by Tulasne to the germinating filaments was promycelium, and he called the secondary small ovoid cells sporidia. In the case of *Puccinia Graminis*, according to De Bary, the sporidia do not grow except on the common barberry, on which plant they produce in the spring or early summer what is popularly called a cluster-cup, or in botanical language an aecidium. The so-called aecidium is a complex affair. The mycelium from the germinating sporidia produces in spots a swelling and discoloration of the barberry leaves. The spots are more or less of a reddish-yellow color, and there soon appears on the upper side of the leaves a number of minute, deep brown pustules called spermogonia. A section through the spermogonia shows that they are cavities lined with slender filaments, the tips of which, called spermatia, separate and escape in masses from the spermogonia. Soon after the appearance of the spermogonia on the upper side of the leaves, the lower surface swells and bears a number of cups, the aecidia proper. The cups are really formed inside the leaf, and are sacks composed of a cellular covering or peridium, and orange-colored spores arranged in rows arising from the base of the peridium. When they come to the surface, the peridia rupture and the spores readily escape. The aecidial spores germinate upon different grasses, and produce in summer what is called the rust, that is, spots or lines containing a rusty colored powder. The rust stage is called by botanists the uredo and consists of rather delicate, oval, unicellular spores of an orange-red colour, often called stylospores, attached to a mycelium. Like the aecidial-spores, the uredo-spores easily fall from their attachment, and germinate on grass and produce late in the season the pustules which bear the teleutospores already described.

As has already been remarked, these different stages were kept as distinct species by

<sup>1</sup> Recherches sur le développement de quelques champignons parasites. Annales des Sciences naturelles. 4 Série. Tome 20, 1863.

Neue Untersuchungen über Uredineen. Monatsber. Akad. Wiss. Berlin, 1865-66.

older writers. The teleutospore condition was called *Puccinia Graminis*; the uredo condition *Uredo linearis*; and the aecidial condition *Aecidium Berberidis*. Recent writers merely speak of the species *Puccinia Graminis*, including by that all the different stages. To designate the old *Aecidium Berberidis* they say *Puccinia Graminis*, fungus hyaline-iferus, and to designate the *Uredo linearis* they say *Puccinia Graminis*, fungus stylosporiferus. Or more briefly one says *Puccinia Graminis* (Uredo) or (Aecidium) as the case may be. To understand at once what is meant by the different expressions one must be acquainted with the literature of the development of the different species, and that is a difficult matter for us in America, since the observations on the subject are scattered in numerous journals, some of which are seldom met with in this country.

Since the development of *Puccinia Graminis* is probably as well known as that of any species of the order, and is furthermore, the species in which the development was first studied by De Bary, we may use that as a type in studying other members of the order. The development is represented in four different stages, viz.:

1. **Teleutospores** on grass in the autumn.
2. **Promycelium** and **Sporidia** produced in spring directly from the teleutospores.
3. The **Aecidium** produced in May or June on the *barberry*, comprising two sets of organs, the **Spermogonia** with their spermatia and the cups or **Aecidia** proper.
4. The **Uredo** produced on grass from the spores of the Aecidia.
1. **Teleutospores** produced from the uredo-spores.

There is a cycle of four different stages; which, taken together, constitute the life of the individual *Puccinia*. It will be remarked that two of the stages are found on grass, one on barberry, and one is produced directly from the teleutospores wherever they may be. At present we are only interested in the genus *Puccinia* in so far as it is a type of the order, and we must next see how far the other species of the order agree with *Puccinia Graminis*. In the first place, if we consider the species of *Puccinia* alone, we find that it is only in certain species that aecidial and uredo conditions are supposed to exist. In some species, as *P. Malvacearum* Mont., only teleutospores are believed by some to occur. In *P. anemones* Pers., uredo-spores are unknown; in a large number of species aecidia are unknown. Furthermore, in case of the species in which all the different stages are known to occur, some have them all produced on the same host-plant, while others, as we have seen in *P. Graminis*, bear them on different plants. It may be asked whether in the cases where aecidial or uredo conditions are unknown, we are not to expect that they will be hereafter discovered. Such is probably true in most cases, but still there are species, as *P. malvacearum*, in which it has been supposed that they are absolutely wanting. For the purpose of expressing the presence or absence of the different stages and their relative position, Schroeter divided the genus as follows:

**EUPUCCINIA.** All stages known and all on the same plant.

**HETEROPUCCINIA.** All stages known. Aecidia and spermogonia on one plant, uredo and teleutospores on another plant.

**HEMIPUCCINIA.** Only stylospores and teleutospores known, and both occurring simultaneously on the same plant.

**PUCCINIOPSIS.** Spermogonia, aecidia, and teleutospores known and on different individuals of the same species. Uredo unknown.

MICROPUCCINIA. Only teleutospores known. Spores quickly detached but not germinating except after a considerable interval.

LEPTOPUCCINIA. Only teleutospores known. Spores persistent, germinating quickly.

From the above named divisions it is evident that there is no want of variety in the genus *Puccinia*, or perhaps it would be better to say that there is a very considerable ignorance of the forms which may occur. Turning from *Puccinia* to other genera of the order, in *Uromyces*, of which the teleutospores differ from those of *Puccinia* in being one-celled, we have the same variations in the presence or absence of the different stages and Schroeter divides the genus in a similar way, into *Euromyces*, *Hemiuromyces*, etc. In the genus *Gymnosporangium*, which differs from *Puccinia* in its gelatinous nature, only aecidia and teleutospores are known. In *Cronartium* aecidia are unknown. In all the genera the teleutospores are supposed in germinating to produce the characteristic promycelium and sporidia, although as I shall have occasion to remark later, this is subject to modification, while the aecidial spores and stylospores germinate by giving out one or more germinal filaments as is the case with the spores of most fungi. In the aecidia the spores are always either orange colored or brownish, and are formed in chains which arise from a sort of placenta formed by the mycelium, at the base of the cellular sack known as the peridium. Spermogonia are present in the aecidial stage, and are developed earlier than the cups, or aecidia proper. The relative abundance and position of the spermogonia with respect to the aecidia themselves, vary in the different species. They are sometimes on different sides of the leaves, as in *Puccinia Graminis*, sometimes mixed rarely on different parts of the plant. The uredo forms of the different genera vary more than the aecidial forms. As a rule the spores are borne singly, but in some genera, as *Coleosporium*, they are in chains. The so-called peridium found in the aecidia is wanting in the uredo forms, but there is sometimes a false peridium formed from the cells of the host plant, or the spots are surrounded by a circle of sterile cells, called paraphyses, derived directly from the mycelium. Spermogonia are usually wanting, but are found in a few cases. The teleutospores of the different genera vary greatly in several respects; they may be unicellular, as in *Uromyces* and *Melampsora*; two-parted, as in *Puccinia* and *Gymnosporangium*; or many-celled, as in *Phragmidium* and *Xenodochus*. They may vary from gelatinous, as in *Gymnosporangium*, to dense and indurated, as in *Melampsora*. They may rise above the surface of the host plants in columns, as in *Cronartium*, or may be sunk among the epidermal cells, or even produced within them, as in *Melampsorella*. The principal generic distinctions are derived from the characters of the teleutospores, but as far as possible, continental writers have regard to the respective aecidial and uredo forms. The genera are perhaps not in all cases well marked, but they are at least quite as well defined as in the other orders of fungi.

In studying the Uredineae of the United States, one, for several reasons, naturally begins with the genus *Gymnosporangium*. The species of the genus are comparatively few in number, and are, with us, found only on different Cupressineae. The teleutospores occur in spring or early summer, and resemble those of *Puccinia* in being generally though not always two-celled, but differ from them in being borne on very long hyaline stalks, the whole being imbedded in a mass of jelly which in moist weather swells up and forms the

orange colored masses, which are supposed by many to be the flowers of the cedar-trees. Probably in no part of the world are the species so abundant as in the eastern United States, and material for study can be procured in the greatest abundance. In one respect this abundance has its advantages, in another it has its disadvantages. The Gymnosporangia of Europe, compared with our own, are few in number and much less abundant, the number of species found in central and northern Europe being limited by Oersted and Reess to three. Oersted, of Copenhagen, was the first to study their development. He connected the gelatinous teleutosporic stages which occur on species of *Juniperus* with the elongated cluster-cups placed formerly in the genus *Roestelia*, which are found in summer on the leaves of different Pomeae, thorns, pears, apples, etc. He went so far as to connect each of the three species of *Gymnosporangium* found in Denmark with a particular species of *Roestelia*. The experiments of Oersted consisted in sowing the germinating sporidia of the *Gymnosporangia* on leaves of different Pomeae. I shall have occasion to return to this subject later, but it is sufficient to notice in this connection that Oersted's<sup>1</sup> observations were afterwards confirmed by De Bury<sup>2</sup> and others in Germany, Cornu<sup>3</sup> in France, and Cramer<sup>4</sup> in Switzerland, and accordingly the genus *Roestelia* has been suppressed by recent continental writers, who refer to the species formerly placed in that genus as the aecidial or hymeniferous stage of the different *Gymnosporangia*.

If one then would study the American species of *Gymnosporangium* in the light of modern research, he must also take into account the different *Roesteliae* of which we have an abundance. The first step is to settle the species of the two genera on anatomical grounds, and then by cultures or observations in the field to ascertain their genetic relations. I insist on the importance of first defining the species from their anatomical structure, for unless this is done any cultures which may be made can have very little value and one is constantly groping in the dark. One may afterwards modify his view of the species in consequence of knowledge derived from artificial cultures, but one should not, for instance, conclude at once, because the sporidia of a given species of *Gymnosporangium* produce spermogonia when sown on the leaves of two plants which are known to have *Roesteliae* differing in their morphological characters, that the two *Roesteliae* are the same species in spite of their different appearance. In determining the species of the two genera one is obliged to ascertain which of our species are the same as those found in Europe; and here a difficulty arises, for one is not quite sure in some cases how far a European species of fungus may vary from the type when growing upon a different host from the one on which it occurs in Europe. In this case one would gladly resort to artificial cultures to settle the question. Unfortunately for us who are obliged to follow in the steps of Europeans in so far as the determination of species common to both continents is concerned, European writers have not agreed amongst themselves as to the limits of

<sup>1</sup> Bot. Zeit., 1865, 291; and 1867, 222. Nouvelles observations sur un champignon parasite dont les générations alternantes habitent sur deux plantes hospitalières différentes. Bulletin de l' Académie Royale des Sciences de Copenhague, 1866.

Nouveaux essais de se nis faits avec des champignons parasites. Loc. cit., 1867.

Om en saeregen, hidtil ukjendt Udvikling hos visse Snyl-

tesvampe og navnlig om den genetiske Forbindelse mellem Sevenbommens Baevrerust og Paeretraeets Gitterrust. Copenhagen, 1868.

<sup>2</sup> Bot. Zeit., 1865, 222.

<sup>3</sup> Bull. Soc. Bot. Tome 25, pp. 122, 221, &c.

<sup>4</sup> Ueber den Gitterrost der Birnbäume und seine Bekämpfung. Schweizer. landwirthschaft Zeitschrift. Solothurn, 1876.

their species. Reess<sup>1</sup> is the most recent writer who has given the synonymy in detail, and I have in most cases followed his account, and have only given in full the special American references.

The greater part of the present paper is devoted to an account of the morphological characters of the species of the two genera found in this country, and I have been unable by means of cultures to arrive at as definite results as I should desire; but a record of one's failures is hardly less important, than an account of one's success. I have myself collected large quantities of Gymnosporangia and Roesteliae in the region around Boston, and I am greatly indebted to Mr. H. W. Ravenel, of Aiken, and Dr. J. H. Mellichamps of Bluffton, for material from South Carolina; to Mr. J. B. Ellis of Newfield, N. J., and Mr. C. H. Peck, the State Botanist of New York, for valuable notes as well as specimens; to Mr. C. B. Fuller for specimens from Portland, Me., and to Dr. H. W. Harkness for specimens from California. I must particularly express my indebtedness to Dr. M. Cornu of Paris, for his notes on European and American species, as well as for a valuable series of specimens, and to Prof. C. Cramer, of Zurich. I have examined the specimens in *Herb. Curtis* to which reference is made by Berkeley in *Grevillea* Vol. III., p. 55-59, the specimens in the Sprague collection of the Boston Society of Natural History, and some original specimens of Schweinitz, which, however, were not in a good state of preservation, besides numerous series of *Fungi Exsiccati* published in Europe and this country.

#### GYMNOSPORANGIUM De Cand.

Spores yellow or orange-colored, usually two-celled, occasionally one- to six-celled, on long hyaline pedicels, imbedded in a mass of jelly which when moistened swells into columnar or irregularly expanded masses. Mycelium parasitic in the leaves and branches of different Cupressineae, producing in them various distortions.

The different genera in which the species of the present genus were placed by writers previous to De Candolle, are given in detail in the paper of Reess and need not be repeated here. The genus was first described by De Candolle from unpublished papers of Hedwig in the *Flore Française*, Vol. II., 1805. Link<sup>2</sup> in 1809 separated the species in which the gelatinous substance was more or less conical or cylindrical, from those in which it was irregularly shaped, placing the former in *Podisoma* and retaining the latter in *Gymnosporangium*. The two genera of Link have, until a comparatively recent time, been kept distinct by European writers, and they were adopted by Schweinitz in the *Synopsis Fung. Am. Bor.*, and by nearly all recent American writers. That the distinction depending merely on the shape of the gelatinous masses should not be called generic, is the opinion of probably a majority of the mycologists of the present day, although a number still keep the genus *Podisoma*. Accepting *Gymnosporangium* in its widest sense as adopted by European writers, we have a genus whose teleutospores are two-celled like those of *Puccinia*, but invested with a variable amount of colored jelly which assumes a more or less definite shape in the different species. Accepting also the opinion first advanced by Oer-

<sup>1</sup>Die Rostpilzformen der deutschen Coniferen. Abhandl. Naturf. Gesellschaft. Vol. xi. Halle, 1869.

<sup>2</sup>Observations in *Ordinis plantarum*, 1809.

sted the accidial stage is found in the so-called Roesteliae which are found on different species of Pomeae but no indications of a uredo-stage have as yet been detected.

An acquaintance with some of the more recently discovered American species shows that the original limits of the genus must be extended so as to include species in which the spores become several (3-6) celled, and in which the amount of gelatinous substance found is comparatively small. In other words, as far as can be judged from the teleutosporic condition, the genus evidently approaches *Phragmidium* in *G. Ellisii*, which species cannot well be placed in a separate genus, as was done by Körnicke<sup>1</sup> in forming his genus *Hamaspora*. The teleutosporic condition of *Gymnosporangium* unlike that of most of the other genera of Uredineae of temperate regions, is found in the spring, and the species of the United States occur only on species of *Juniperus*, *Cupressus*, and in California on *Libocedrus*. The production of the promycelium and sporidia is seen with the greatest ease and, in fact, after a shower the orange-colored masses are covered with the latter. When, however, the masses after having been wet are quickly dried, instead of a production of sporidia from the promycelium, the latter divides quickly into a number of cells which separate from one another, and which on remoistening send out germinal tubes just like the sporidia. A similar transformation of the promycelium was noticed by Cramer, loc. cit., p. 7, in *Gymnosporangium fuscum* growing in Switzerland. In the Northern States the teleutospores make their appearance usually from the middle of April to early in May according to the season, reach perfection in May and disappear at the end of June. In the South they are found considerably earlier.

The principal characters used in distinguishing the species are the shape and size of the gelatinous masses, the shape and size of the spores, and the number of cells of which they are composed, the number and position of the promycelia produced from each cell, and the form and character of the swellings or distortions produced in the plant on which they are parasitic. The particular shape of the gelatinous masses in any given species depends considerably upon the age and amount of moisture, and in all species, after having been repeatedly expanded by numerous showers and again dried, they become amorphous. When first appearing after the rupture of the epidermis, or outer bark, they are in the form of cushions of a dark velvety color. As they reach perfection, the forms they assume may be divided into three; the cylindrical, which may be either blunt or acutely attenuated; the flattened or wedge-shaped, which are usually blunt and crenate or partly divided; and the irregularly expanded, which are broadly ovate or flattened and generally plicate. The usual number of cells is two, but even in species which normally have only two cells, one sometimes finds three or four cells. The single-celled spores are generally immature, but occasionally they bear promycelia. In two of our species the normal number of spores is greater than two. The number and position of the promycelia given off from each cell varies considerably in the same species. As a rule, they are not borne at the apex of the cells, but near the line of union of two cells. They are occasionally produced from the apex, and in one species, that seems to be the common position. In some species the usual number of promycelia to each cell is four, in others only one or two. The length of the promycelia depends upon the position of the spores in the gelatinous mass. Those on or

<sup>1</sup> *Hedwigia*. Vol. xvi, p. 22. 1877.

near the surface have short promycelia, while those of the interior have very long ones, the object evidently being that the tips which bear the sporidia may reach the light and air.

One of the most curious and interesting phenomena connected with the growth of Gymnosporangia is the peculiar distortions which they produce in the plants on which they are parasitic. The mycelium does not differ much from that commonly found in the other Uredineae. It is irregular, much branched, and cross partitions are rather numerous. Unlike, however, the mycelium of some of the Pucciniae, that of the species of the present genus is limited in extent, and is not found throughout the whole of the plant on which it is growing, but is confined to certain portions of the stems or leaves. The mycelium of most of the species is perennial, that is, the mycelium which has produced a crop of spores one year, will the next year, under ordinary circumstances, produce another crop in or near the same place. One species, however, and possibly others are annual, the spores of one year not following those of another in the same place. The kinds of distortion produced vary with the species, but it is probable, although not absolutely certain, that the same species produces different deformities when growing on different species of plants. This we might perhaps account for by a difference in the histological character of the two plants, but exactly why two different species of Gymnosporangium parasitic on the same individual cedar, should produce two widely distinct deformities is less easily explained. In the mere appearance of the mycelium itself, one can not see any cause for the different growths produced.

The explanation is evidently to be sought in the amount and extent of the mycelium, the rapidity of its growth, and its duration. Thus in a rapidly growing annual species, as *G. macropus*, we have a large, rather spongy excrescence which shrivels in drying. In *G. fuscum* var. *globosum*, which is perennial, and of slower growth, the excrescence is more dense and scarred externally. In *G. biseptatum* the mycelium is comparatively limited in amount, and does not increase rapidly, and in consequence, the formation of the annual woody layers is not prevented, nor the nutrition of the branches above much interfered with. The mycelium is found principally in the region of the cambium, and acts rather as a stimulant than as a destructive agent, and the result is that a nodose swelling is formed in consequence of the unusual development of the wood in the region of the fungus. In *G. Ellisii*, which like the previous species, grows on *Cupressus thyoides*, there is a more luxuriant and rapidly growing mycelium, which extends for some distance along the smaller branches, and is so abundant as to interfere with the nutrition and, in consequence, the branches above become short and stubby, and, at length, densely fasciculated, the branch below the fungus remaining unchanged, so that we have, instead of a nodose swelling, a dense tuft of short branches borne on the end of a normal branch. In other species the mycelium traverses the leaves, which are distorted throughout, so that the branches infested by the fungus and those free from the fungus, seem to belong to different species, so regular is the hypertrophy of the leaves. In this connection it may be remarked that in some places the distortions are not altogether due to the direct action of the fungi themselves, but are produced in part by the secondary action of the disordered nutrition combined with the effect of the weather. Nor can one infer from the

amount of the gelatinous expansion on the exterior, how destructive a particular species is to the plant on which it is growing. *G. macropus*, for example, is much more striking to the eye than *G. clavipes*, but the latter is more destructive to the plants upon which it grows.

### GYMNOSPORANGIUM ELLISII (Berk.).

Plate 2, figs. 13-17.

*Podisoma Ellisii* Berke., Grevillea, Vol. III, p. 56; Farlow, Bull. Bnssey Inst., Vol. II, p. 226. Exsicc. Thümen, Herb. Mycol. Oeconom., 440.

*Hamaspora Ellisii* Körnicke, Hedwigia, Vol. XVI, p. 22.

*Gymnosporangium Ellisii*, in Ellis's North American Fungi, Fasc. III, No. 271.

Sporiferous masses numerous, scattered, cylindrical, filiform, from one-eighth to a quarter of an inch high; spores dark yellow, linear-fusiform, obtuse, usually 3-4 celled, sometimes 1-5 celled,  $10\mu$ - $16\mu$  in diameter,  $75\mu$ - $190\mu$  long, average  $120\mu$ - $150\mu$ ; pedicels long and slender; promycelia short and much curved, usually one from each cell. Mycelium perennial, distorting the smaller branches.

On *Cupressus thyoides*.

Newfield, N. J. (Ellis); Newton, Dedham, Wood's Holl, Mass. (Farlow).

This is one of the many interesting species of fungi discovered by Mr. J. B. Ellis at Newfield, N. J. Previous to May, 1872, when it was first seen by Mr. Ellis, the species was quite unknown, although it is apparently not uncommon in the so-called cedar swamps along our eastern coast. It is the smallest and least gelatinous of the genus, but the trees attacked by it may be recognized, even at a considerable distance, by the peculiar distortions, which consist in a dense fasciculation of the smaller branches in different parts of the tree, so that, when viewed from a distance, one sees closely branching tufts of a somewhat fan-shaped or corymbose outline, which appear to terminate some of the branches. The fungus itself is only visible on close inspection. The branches affected are thickly covered with the sporiferous masses, which, when dry, are of a reddish-brown color, not very different from that of the bark itself, and which, when moistened, are orange-colored, and not generally more than from an eighth to a quarter of an inch long. The species is often associated with *G. biseptatum* which produces an entirely different distortion, affecting generally the larger branches. The leaves themselves are, however, but little distorted by the present species. The mycelium of *G. Ellisii* is of rather large size and in cross sections of the stems is seen to follow the medullary rays, sometimes extending nearly to the centre of the stem, and occasionally forming partial circles between the annual rings. In longitudinal sections of affected branches one sees the mycelium collected in brownish spots which extend far into the wood. The greater part of the mycelium is found near the cambium and it collects in masses in the bark to form the sporiferous bodies which originate at some little distance beneath the surface. The mycelium is perennial and extends gradually along the branches sometimes for a distance of eighteen inches, and they swell to about once and a half their normal diameter.

The spores of *G. Ellisii* are very striking and differ from those of the rest of the genus in being very long and narrow and in being usually more than two-celled, the most usual numbers being three and four. The amount of jelly in the sporiferous masses is less than in other species, and in consequence dried specimens give a better idea of the fungus as it appears in nature than is generally the case in the present genus. The promycelia are very abundant and very short, the lower sterile part found in other species being almost wanting and the part bearing the sporidia being much curved, so that the promycelia coming from the cells of one spore sometimes wind round and enclose another spore, making dissection difficult without tearing off the promycelia. One not unfrequently finds spores in which the upper cell is more or less deeply cleft, as in Pl. 2, fig. 17.

In spite of the fact that in certain details, *G. Ellisii* differs from the majority of the other species of *Gymnosporangium* it seems to me that Körnicke<sup>1</sup> is not warranted in establishing a new genus *Hamaspora*, founded on two species, *G. Ellisii* growing on *Cupressus thyoides* and *Phragmidium longissimum* Thüm. growing on *Rubus rigidus* at the Cape of Good Hope. In the first place, the gelatinous substance is not wanting in *G. Ellisii*, as can easily be seen in examining fresh specimens, and furthermore, the fact that the spores are more than two-celled is equally true of *G. biseptatum*, a species which undoubtedly belongs to *Gymnosporangium*. On the other hand, in *H. longissima* Körnke., admitting that the teleutospores bear a great resemblance to those of *G. Ellisii*, the specimen in *Mycotheca Universalis*, No. 542, shows an abundance of uredospores surrounded by the circle of large paraphyses generally found in the uredo-spots of *Phragmidium*, while in *G. Ellisii* there are no uredo-spores at all. When we consider also that the species of *Phragmidium* generally occur on species of *Rubus* or related genera, and *Gymnosporangium* only on Coniferae, it would certainly seem that *H. longissima* should be kept in *Phragmidium* where it was placed by Von Thümen, and that *G. Ellisii* should be retained in *Gymnosporangium*. I am perfectly willing to admit that the last named genus approaches the former, but the matter is not helped by creating a third genus less clearly marked than either of the others.

The present is more limited in its range than our other species, as far as at present known. It probably has often been overlooked, on account of its small size, and may occur wherever the white cedar, *Cupressus thyoides*, is found. It is certainly common in such localities in Massachusetts, and in passing from Boston to Washington by railroad, I have seen the peculiar distortions along the whole route wherever the white cedar occurred.

#### GYMNOSPORANGIUM CLAVARIAEFORME De Cand.

*Gymnosporangium clavariaeforme* D. C., Flore française, Vol. II, p. 217; Reess, loc. cit., p. 21. Exsicc. Ellis, North American Fungi., Fasc. III, 273.

*Podisoma clavariaeforme* Duby, Bot. Gall., Vol. II, p. 881. Oersted, Nouveaux essais de semis. Pl. 3 and 4.

*Podisoma Juniperi communis* Fr., Syst. Myc., Vol. III, p. 548.

<sup>1</sup> Hedwigia, Vol. XVI, p. 22.

*Podisoma Juniperi* Cooke, Decades of Maine Fungi,<sup>1</sup> p. 183; Notes on *Podisoma*,<sup>2</sup> Pl. 19, fig. 1.

Sporiferous masses numerous, scattered or aggregated, yellowish-brown when dry, bright yellow when swollen, cylindrical or slightly compressed, acute or occasionally forked at the apex, from a quarter to half an inch high, spores narrowly lanceolate, those on the outside of gelatinous masses clavate, two-celled,  $13\mu$ - $19\mu$  broad, by  $55\mu$ - $90\mu$  long; promycelia usually one or two from each cell. Mycelium perennial, causing long fusiform swellings of the branches.

On *Juniperus communis*.

Portland (C. B. Fuller); Cape Elizabeth, Me. (E. C. Bolles); Maine, without locality, in Herb. Curtis (M. B. Blake, No. 579). Northern and Central Europe.

Apparently not a common species in the United States and known to me only as occurring in Maine. It is said by Mr. C. B. Fuller to be common on the ground cedar in the islands in Portland Harbor, and some of the specimens collected by him were distributed by Ellis in North American Fungi. The species is not known to occur on leaves in the United States, but is found on the larger branches, which swell for a considerable distance to nearly twice their normal size, and become cracked on the surface. The sporiferous masses are quite yellow when swollen, and are not dark colored when dry, as in the case in *G. fuscum*. They are rather slender and pointed at the apex, and, although sometimes a little flattened, are not decidedly compressed as in some other species. I have never in American species seen the apex flattened and expanded, as is shown in the figure of Bulliard referred to the present species by DeCandolle. The Portland specimens collected by Mr. Fuller bear the closest resemblance to No. 1088, of Rabenhorst's Fungi Europaei, Series Nova. The spores, compared with those of our other two-celled species, are long and narrow. Those borne on the outside of the gelatinous masses are clavate, or have the upper cell broader than the lower, and obtuse at the apex, but the spores in the interior are attenuated at both extremities as in *G. macropus*, but they are distinctly longer and more slender than the latter. The promycelia are, as a rule, fewer in number than in *G. macropus*, and one generally sees only one or two given off from each cell. In Europe the species is said also to occur on the leaves of *Juniperus communis*, and probably a close examination of plants affected will show that such is the case also in this country. The specimen in Herb. Curtis collected by Mr. Blake, is not in sufficiently good condition to show the shape of the sporiferous masses, but the spores suffice to show that the specimen belongs to the present species rather than to *G. fuscum*.

GYMNOSPORANGIUM MACROPUS Lk.

Plate 2, figs. 1-6.

*Gymnosporangium Juniperi virginianae* Schw., Syn. Fung. Carol., Sup., p. 74, No. 504. 1822.

*Gymnosporangium macropus* Link, Species Plantarum, Vol. vi, part 2, p. 128. 1825. Exsicc. Ellis, North American Fungi, Fasc. 3, No. 270.

*Podisoma Juniperi virginianae* Fr., Syst. Myc., Vol. III, p. 57. 1832.

<sup>1</sup> Proc. Portland Soc. Nat. Hist. Vol. I, II, 1869.

<sup>2</sup> Journal of Quekett Microscopical Club, Nov. 1871.

*Podisoma macropus* Schw., Syn. Fung. Am. Bor., p. 307, No. 3096, 1831; London Jour. Bot., Vol. iv, Pl. 12, fig. 6; Sprague's Contributions to New England Mycology,<sup>1</sup> p. 329; Curtis's Plants of North Carolina, p. 121; Peck's 23d Report, p. 57; Notes on Podisoma, Pl. xix, fig. 3; Grevillea, Vol. 3, p. 56. Exsicc. Ravenel, Fung. Car., Fasc. 1, No. 85; Thümen,<sup>2</sup> Mycoth. Univers., No. 148.

Sporiferous masses aggregated in globose tufts, surrounded at the base by a ring formed by the raised epidermis and subepidermal tissue of the host-plant, orange-yellow, cylindrical, acuminate, half an inch to an inch long or, at times, longer; spores ovate-acute, two-celled, generally constricted at the septum and with a papilla at the apex,  $15\mu$ - $20\mu$  broad by  $45\mu$ - $60\mu$  long; promycelia generally four from each cell. Mycelium annual, producing globose or reniform knots in the smaller branches.

On leaves and smaller branches of *Juniperus virginiana*.

Common from Massachusetts to South Carolina (Ravenel, Mellichamps), and extending west to Missouri (Englemann), Colorado (Palmer), and Wisconsin (Lapham).

The common "cedar apple" of the Atlantic States, and the most striking species of the genus. It is very abundant along the seaboard, but becomes rarer in the west. The knots together with the sporiferous masses, often measure three inches across when swollen. When dry the sporiferous masses are much shrunken, and as the knots do not differ much in color from the branches, they are not well seen from a distance. The species was first described by Schweinitz, in 1822, under the name of *G. Juniperi virginianae*. Link in 1825, described it in the Species Plantarum (Linnaeus and Willdenow), under the name of *G. macropus*, but why the Schweinitzian name was suppressed, or why Link placed the species in *Gymnosporangium* rather than *Podisoma*, a genus of his own creation, is not clear. In 1831, in the Syn. Fung. Am. Bor., Schweinitz adopted Link's specific name, but placed the species in *Podisoma*, and it has generally been known since as *Podisoma macropus* Schw. Fries, however, retained Schweinitz's original specific name, and called our plant *Podisoma Juniperi virginianae*. Notwithstanding that Schweinitz's name given in the Syn. Fung. Carol. Sup., is the oldest, it must be abandoned in consequence of the confusion and awkwardness which has arisen from applying the compound names *Juniperi virginianae*, *Juniperi communis*, *Juniperi Sabinae*, etc., to denote the different species. The present species, moreover, is by no means the only one found on *J. virginiana*, and it is on all accounts desirable to retain the name given by Link, and afterwards adopted by Schweinitz himself, at least as far as the specific name is concerned.

The mycelium of *G. macropus* is abundant, and easily seen. It is found principally in the leaves, and there are haustoria which enter the parenchymatous cells. The fungus causes the leaves to swell, and finally ruptures them at about the central portion. One then sees a rounded mass tipped with the comparatively unchanged apex of the leaf. In some cases the gelatinous columns are produced when the knot is quite small, so that not

<sup>1</sup> Proc. Boston Soc. Nat. Hist., Vol. v. 1856.

<sup>2</sup> Streinz, Nomenclator Fungorum, p. 455, gives Wyman as the authority for the species and in this error he is followed by Von Thümen. The Wyman in question was Prof. Jeffries Wyman, whose only connection with the species con-

sisted in sending a letter with a drawing of the fungus to Berkeley, asking the name of the species. The letter and Berkeley's reply that the fungus was *Podisoma macropus* Schw. were published in London Jour. Bot., loc. cit.

more than two or three columns can find attachment, but generally the knots grow to from half an inch to an inch and a half in diameter, before the gelatinous masses break through the surface. The latter arise a short distance below the surface, and the outer portion of the knot consisting of several layers of cork cells is raised in flattened papillae. By the growth of the gelatinous masses the centre of each papilla is ruptured, and the columns rise vertically. The margin of the raised papilla remains behind, as a sort of collar around the base of each sporiferous mass.

The shape of the fully developed knots is peculiar. In consequence of the fact that the cells of the outer part of the knots multiply more rapidly than those near the base, the knots become convex on the upper side and finally reniform, and are contracted beneath and attached by a small base. It has generally been supposed that the knots are usually outgrowths from the smaller branches, but such is not the case and, as far as I have been able to ascertain, they originate in a leaf. When the knots have attained a considerable size they appear to be terminal, because the branch above is pushed to one side. The young knots begin to appear about the end of August, and often reach a considerable size before winter. In the latitude of Cambridge, the gelatinous masses do not naturally appear before May or, exceptionally perhaps, in April, but if knots are gathered in February or March and placed in a warm, moist place, they may be made to appear in from ten days to a fortnight. The knots persist after the sporiferous masses have been quite washed away, and from silvery-gray become brown and spongy, the surface being honeycombed, the depressions being the spots from which the gelatinous masses have disappeared. In by far the majority of cases, the knots gradually dry and drop off after having borne one crop of spores. In rare instances, however, a new knot may grow from one side of the old knot and bear a second crop of spores, but in this case the two portions remain quite distinct, one part being old, shrivelled and weather-worn, and the new part succulent, brownish-gray, and covered with sporiferous masses. By the nature of the knots alone one can distinguish between this and the following species. The latter is perennial, and between the sporiferous columns of one year one can easily see the scars of the last year's masses.

As far as concerns the gross appearance presented by *G. macropus*, the account given by Schweinitz in the *Syn. Fung. Am. Bor.* is quite accurate. He states that the species is rare in North Carolina, but common in Pennsylvania. He remarks also "capitulum persistit per annum," from which one may infer that he recognized that the species was an annual, a fact which succeeding writers have not sufficiently regarded. His description of the cedar-apples themselves is so minute and accurate that there can be no doubt that Schweinitz had either never seen the form described on a succeeding page as *G. fuscum* var. *globosum*, or at any rate clearly distinguished it from *G. macropus*. In the letter of Wyman, published by Berkeley in the *London Journal of Botany*, Vol. iv, p. 316, an account is given of the germination of the spores and the distortions supposed to be produced by *G. macropus*, but it is evident from the description that Wyman had confounded *G. macropus* and *G. clavipes*. He says "I have made numerous searches for these parasites, but have almost never detected them, except in the localities mentioned, viz.: the tufts composed of acerose leaves and the "cedar apple." The tufts with acerose leaves are not identical, as I believe, with the variety of form which occurs in the young shoots of the

*J. virginiana*, described in Bigelow's Med. Botany and by yourself (Sir J. W. Hooker to whom the letter was originally addressed), in the Flora Boreal. Amer., also in the description of the *J. bermudiana* in the London Journal of Botany for March 1843. The form of the leaf is in both cases acerose, but the tuft to which I refer forms a single dense mass, the twigs so crowded together as scarcely to allow the light to pass through, looking at a distance like the nest of some bird. These masses vary in size from that of the first to eighteen inches in diameter. Generally not more than one mass is seen on the same tree, sometimes, however, two or three. I have never seen a single tuft like those described in which the fungus in question was not present, and this is the result of a great number of observations." Ths description of the acerose leaves and the dense growth of the branches, which look in the distance like bird's nests, is excellent, but the species which causes this distortion of the branches is not *G. macropus* but *G. clavipes*, a distinct species as we shall see hereafter, and one having no connection with the cedar-apples proper. The figures of Wyman represent the spores of *G. macropus*, except that some of them appear to be germinating at the tip in the mode characteristic of *G. clavipes*.

The species is very widely distributed and is, as a rule, very common, but is not recorded in some localities where one would have expected it. Mr. Peck informs me that it is not common near Albany, N. Y., and it is not mentioned in Tuckerman's Catalogue of the Plants growing near Amherst. It is certainly very common in Eastern Massachusetts, New Jersey, Pennsylvania and Maryland, and although said by Schweinitz to be rare in North Carolina, has been found by Ravenel and Mellichamps to be common in South Carolina. The comparative scarcity of *J. virginiana* in the Western States would account for the absence of *G. macropus* in many Western localities. The injury done to the trees affected is comparatively slight, as was remarked by Schweinitz, and the reason for this is apparent if we consider the short duration and the mode of growth of the mycelium. The cedar-apples are said to be used as anthelmintics and the United States Dispensatory gives as the dose ten to twenty grains three times a day. In Massachusetts the use of the apples as medicine is, as far as I can ascertain, unknown, and the practice is probably confined to Pennsylvania and the Southern States.

The spores of *G. macropus* are pretty uniformly ovate and acute at both extremities, and although they bear a certain resemblance to those of *G. clavariaeforme*, they are markedly shorter and broader. Schroeter suspects that *G. macropus* is only a form of the last-named species, but the fact that there is a difference in the spores and that one is annual and the other perennial, not to mention the difference in habit, clearly forbids a union of the two.

#### GYMNOSPORANGIUM FUSCUM De Cand.

*Gymnosporangium fuscum* D. C., Flore française, Vol. II, p. 217; Reess, loc. cit., p. 16.  
*Podisoma Juniperi* Link., Observ. I, p. 9; Species Plantarum, Vol. VI, part II, p. 127;  
 Sprague in Proc. Boston Soc. Nat. Hist., Vol. V, p. 329; Frost in Tuckerman's List of  
 Plants of Amherst.

*Podisoma Juniperi Sabinae* Fr., Syst. Myc., Vol. III, p. 508.

*Podisoma fuscum* Duby, Bot. Gall., Vol. II, p. 881; Cramer, Ueber den Gitterrost der Birnbäume, Pl. I.

*Podisoma Sabinae* Oersted, Om en sacrege hidtil ukjendt Udvikling, etc., Pl. I.

Sporiferous masses numerous, generally approximated, brownish when dry, dark orange when swollen, a quarter to half an inch high, compressed-conical, or wedge-shaped, upper margin thick, rounded, sometimes notched; spores roundish ovate, two-celled, frequently constricted at the septum,  $38\mu$ - $53\mu$  long, by  $15\mu$ - $22\mu$  broad; upper cell either nearly hemispherical or obtuse; promycelia generally four from each cell. Mycelium perennial, causing long swellings of the branches.

On stems of *Juniperus virginiana* and *J. communis*.

Near Boston (Sprague); Amherst, Mass. (Frost); Catonville, near Baltimore, on imported species of *Juniperus*, (Farlow). Europe.

This species, although apparently common in Europe, is, in its typical form, rare in the United States. It has frequently been confounded with *Gym. clavariaeforme* from which it differs in the shape and color of the sporiferous masses, which are in *G. fuscum* usually thick and wedge-shaped with a blunt margin, and of rather a dark, blackish brown color, especially when dry, while in *G. clavariaeforme* they are rather slender and cylindrical. It also differs in the shape of the spores, which are shorter and stouter in *G. fuscum*, and usually give off four promycelia from each cell. The spores vary considerably in outline, those on the surface being more decidedly oval and with a thick dark cell-wall, while those in the interior of the jelly are more acute and with thinner cell-walls. As is the case with most of the species where the promycelia are given off near the septum, the two cells at maturity retract from one another at the outer margin and only remain slightly adherent at the centre. The mycelium is found principally in the stems which have attained a certain thickness and causes them to swell for a distance of several inches. The sporiferous masses rupture the outer bark in elliptical spots which may be isolated, or, as is more frequently the case, are rather closely approximated.

In American catalogues and herbaria one rarely finds the specific name *fuscum* applied to the present species, but it usually figures under the name *Podisoma Juniperi* Lk., and occasionally as *P. Juniperi* Fr., which is incorrect, as there is no proper *P. Juniperi* Fr., the name given by Fries to the present species being *P. Juniperi Sabinae*. The name *P. Juniperi* Lk., it must be remarked, has been rather loosely applied in this country to several distinct species, and when occurring in catalogues of fungi allowance has to be made for the determination. In Herb. Curtis, for instance, of the different specimens marked *P. Juniperi*, Lk., one from Maine is *G. clavariaeforme*; one from Pennsylvania (Michener, 949) and one from Hillsboro, N. C., collected by Curtis himself, are *G. clavipes*, and one from Sprague is *G. fuscum*. Specimens which may with certainty be referred to *G. fuscum* are few in number. The specimens of Frost, which I have been unable to examine, were on *J. communis*. Of Sprague's specimens one in the collection of the Boston Society of Natural History, and one in Herb. Curtis are the true *G. fuscum* on what appears to be *J. virginiana*. The spores in Sprague's specimens are rather more slender than in European specimens, being  $46\mu$ - $57\mu$  long by  $15\mu$ - $19\mu$  broad, but in other respects they are quite typical. Whether the *P. Juniperi* of Schweinitz, Syn. Fung. Am. Bor., No. 3095, is to be referred to the present species or to *G. clavariaeforme* is uncertain, the original

specimen which I have examined not being in condition to be determined with accuracy. The only instance where I have myself seen the species growing was on the estate of Mrs. Lerman at Catonville near Baltimore, where several imported Junipers were, in May 1879, badly affected by a fungus which was without doubt *G. fuscum*. I have never collected the present species on *J. virginiana*, but besides the specimens of Sprague already mentioned it was found by Tulasne on *J. virginiana* in France. I am indebted to my friend Dr. Cornu for an opportunity of examining a portion of Tulasne's specimen and it seems to me that the fungus in that case is the same as that collected by Sprague and referred to *G. fuscum*. Dr. Cornu,<sup>1</sup> however, distinguishes between *Podisoma Juniperi Sabinae* and *P. fuscum*, and it is to the first named form that he thinks the specimens found by Tulasne on *Juniperus virginiana* should be referred. The *P. fuscum* on *J. Phoenicea* figured by Gasperrini has been separated by Cooke as a new species under the name of *G. Phoeniceae*.

GYMNOSPORANGIUM FUSCUM, var. GLOBOSUM Farlow.

Pl. 1, figs. 7-11.

*Podisoma fuscum* Cooke, in Notes on Podisoma, p. 10, 1871; Peck, in 25th Report, New York State Botanist, p. 89, 1873; Farlow, in Bull. Bussey Inst., Vol. II, p. 225.

Sporiferous masses densely aggregated, dark brown when dry, yellowish orange when swollen, a quarter to half an inch high, compressed conical or wedge-shaped; spores ovate, sub-acute,  $38\mu$ - $45\mu$  long, by  $19\mu$ - $21\mu$  broad; promycelia usually four. Mycelium perennial, forming globose swellings in the branches.

On the smaller branches of *J. virginiana*.

From Massachusetts (Farlow) to South Carolina (Mellichamp).

The present form probably passed for a variety of *P. macropus* with earlier writers provided it was observed by them at all. It was first noticed by Cooke from specimens collected by Peck, in Notes on Podisoma, and was referred by him to *P. fuscum* Duby. In Peck's Report for 1871, published in September, 1873, the species was also referred to *P. fuscum*. It is very common in the Atlantic States on *Juniperus virginiana*, on which it forms globose knots resembling those made by *G. macropus* in some respects, but smaller and less striking. The mycelium is perennial and abounds in the stems and leaves. The fungus, unlike *G. macropus*, does not break through the central part of the leaf, but bursts through the stem at the point of attachment of the leaves, and the knots formed do not assume the reniform outline so common even in the early stages of *G. macropus*, but are more nearly globose and on the surface appear of a dark mahogany color, rather than silvery gray as in *G. macropus*. The knots grow comparatively slowly and last for several years, bearing several successive crops of spores. The sporiferous masses rupture the surface irregularly and they are not surrounded by so distinct a ring at the base as is the case in *G. macropus*. The gelatinous masses are broad and flattened at the

<sup>1</sup> Présence du *Podisoma Juniperi Sabinae* sur le *Juniperus virginiana* et sur divers autres Genévrier : Bull. Soc. Bot.,

base and taper upwards, but are comparatively broad and flattened even at the apex. The scars left by the sporiferous masses of the previous year are distinctly visible between the bases of the newly formed masses. The knots seldom attain a great size and rarely exceed an inch in diameter. They usually appear to be terminal on the smaller branches, but sometimes they form nodes in the continuity of the branches. In course of time the surface of the knots becomes grayish and irregular by the action of the weather, but they are always more compact and harder than the knots of *G. macropus*. The leaves are not usually distorted by the fungus, but when the knots are large, the leaves on the upper branches above the knots become somewhat hypertrophied.

What we have called variety *globosum*, is certainly common in the Eastern States. It often accompanies *G. macropus*, and is in Eastern Massachusetts about as common as that species, and Mr. Peck states that it is still more common in the region of Albany. How far west the variety extends is unknown. The southern limit, as far as I can ascertain, is Bluffton, S. C., where it was collected by Dr. Mellichamp. Although often accompanying *G. macropus*, and like it producing what are popularly called "cedar apples," there is no doubt that the present form is distinct from it as is shown by the fact that it is perennial and not annual, and by the very different character of the knots formed, and the appearance of the sporiferous masses. A very slight experience will enable any one to distinguish between the two at sight. The only question which can arise is whether the fungus in question is distinct from *G. fuscum*, and on this point it is not so easy to give a decided answer. The variety, if indeed it be not a distinct species, differs entirely from the type in the character of the distortions produced on the same host-plant, *J. virginiana*, and it may be said with considerable truth that the same species of fungus could not produce two such different distortions in the branches of the same species of plant. The sporiferous masses, however, are in shape and color much like those of *G. fuscum*, and the spores themselves, the size and shape of which, at the best, are variable even in the same species, although in general smaller than in *G. fuscum*, are not sufficiently distinct to allow one on the strength of their smaller size alone, to separate the fungus as a distinct species. The question is, does not the smaller size of the spores in connection with the peculiar distortions caused by the fungus warrant one in regarding it as different from *G. fuscum*? I think it quite possible that the two are distinct, but am unwilling to speak positively without more information with regard to the mode of occurrence of *G. fuscum* on *J. virginiana* in Europe. So far as I know, however, the globose distortions are unknown in Europe, the only case known to me where a globose mass is figured, being in Cooke's notes on *Podisoma*, Pl. 19, fig. 2, but it is not there stated whether the figure was drawn from a European or an American specimen.

#### GYMNOSPORANGIUM BISEPTATUM Ellis.

Pl. 2, figs. 18-21.

*Gymnosporangium biseptatum* Ellis, in Bulletin of Torrey Club, Vol. v, p. 46, 1874; Farlow in Bull. Bussey Inst., Vol. II, p. 226; Vize in Grevillea, Vol. VII, p. 11; Harkness and Moore, Catalogue of the Pacific Coast Fungi, p. 25. Exsicc. Ellis, North American Fungi, Fasc. III, No. 272.

Sporiferous masses flattened and brownish when dry, becoming hemispherical or oval and rugose when swollen, and of a light yellow color, about a quarter of an inch high; spores linear-oblong, obtuse, two to six celled, most frequently three or four celled,  $50\mu$ - $84\mu$  long, by  $15\mu$ - $20\mu$  broad; promycelia one or two from each cell. Mycelium perennial, forming node-like swellings in the branches.

On leaves and stems of *Cupressus thuyoides*, Newton, Dedham, Wood's Holl, Mass. (Farlow); Newfield, N. J. (Ellis).

On *Libocedrus*, Yosemite, Cal. (Harkness and Moore).

A striking species first found by Mr. Ellis in New Jersey, and although only known apparently in a few localities it is probably common on *Cupressus thuyoides* throughout the Atlantic States. It often accompanies *G. Ellisii* for which, however, it cannot possibly be mistaken. As in that species the distortions produced by *G. biseptatum* can be seen at a considerable distance. The mycelium is perennial, and is found in the leaves and branches, principally in the latter.

In the leaves the mycelium produces no perceptible distortion until the sporiferous masses appear. There is only one mass to a leaf, and it is first seen as a brownish elliptical protuberance emerging from the edge of the leaf. In the stem the distortions are marked and may be seen at a distance. The mycelium is found principally in the region of the cambium, and oval or oblong swellings are formed from one to two inches long, the bark becomes distended and cracked, and the sporiferous masses are found in the fissures, at first in small pulvinate tufts which on swelling form shapeless masses of rather a light yellow. The swellings increase year by year, and at length become very marked, the fungus growing constantly outwards, and producing fresh crops of spores year after year. The swellings are sometimes found in the main trunk of the tree, and I have seen them more than a foot in diameter. However large they may become, the heart wood generally remains firm and hard, and does not become spongy and riddled with holes as is the case with the branches attacked by *G. Ellisii*, which on the whole is decidedly more injurious to the trees than *G. biseptatum*.

The spores of the present species are characterized by the great variability in the number of cells of which they are composed. The most usual number is three or four, two are rather common and occasionally there are as many as six. The spores are rather stout and obtuse, and generally constricted at the septa. When mature and about to produce the promycelia it is usual for the different cells to separate from one another either wholly or in part, as is well shown in Pl. 2, fig. 20. The spores of the present species when fully grown are not easily mistaken for those of any other species, but the young tufts on the leaves often bear spores which are all, or nearly all, two-celled. I have received specimens from Mr. Ellis, with the fungus confined to the leaves, and it was difficult to say to what species to refer it. Large sets of specimens collected at Newton, however, show that while the young spots on the leaves may have principally two-celled spores, those on the smaller branches have about an equal proportion of two and three celled spores, and the still older spots have a large proportion of three-celled spores. In short, the variability is so great that without a large set of specimens, one would have difficulty in convincing himself that the extreme forms belonged to the same species.

Like *G. Ellisii*, the present species, although occurring in localities as remote as Massachusetts and California, is known in only a few localities, but where it occurs it is generally abundant. There can be no doubt whatever, in spite of the unusually large number of cells of which the spores are composed, that the species should be placed in *Gymnosporangium*, and the number of cells only goes to strengthen the view that *Hamaspora* cannot be kept as a distinct genus.

### GYMNOSPORANGIUM CLAVIPES Cooke and Peck.

Pl. 2, figs. 22-27.

*Podisoma gymnosporangium*, var. *clavipes* C. and P., in Notes on *Podisoma*, 1871.

*Gymnosporangium clavipes* C. and P. in Peck's 25th Report, p. 89; Farlow, Bull. Bussey Inst., Vol. II, p. 226; Exsicc. Ravenel's *Fungi Americani Exsiccati*, No. 272.

*Podisoma Juniperi* Herb. Curtis in part.

*Gymnosporangium* sp. Herb. Curtis in part.

Sporiferous masses subpyriform or irregularly globose becoming indefinitely expanded, reddish yellow when dry, orange when swollen, about a quarter of an inch high; spores broadly ovate, obtuse, two-celled, generally constricted at the septum; pedicels broad, much swollen beneath the spores,  $40\mu$ - $60\mu$  long by  $22\mu$ - $38\mu$  broad; promycelia usually two or three from a cell, frequently produced from the apex of the cells. Mycelium perennial in the leaves and branches, producing nest-like distortions.

On *Juniperus virginiana*.

Eastern Massachusetts (Farlow); New York (Peck); New Jersey (Ellis); Pennsylvania (Michener); North Carolina (Curtis); South Carolina (Ravenel).

One of the most unsightly species of the genus and certainly common in the Atlantic States from Massachusetts to Florida. The mycelium is abundant in the leaves and branches and produces peculiar distortions already referred to under *G. macropus*. The leaves swell to double their original size and become sharp pointed and rather spreading. The effect produced will be seen by comparing figs. 22 and 23 of Plate 2, where fig. 23 shows a twig with normal leaves, and 22 one attacked by *G. clavipes*. The branches are somewhat swollen and the branching of the affected ones becomes very dense, so that at a distance it appears as if there were bird's-nests in the boughs. The branches are often distorted for a distance of a foot or a foot and a half. The sporiferous masses are very abundant on the leaves and branches. Those on the leaves appear at their bases where they are adherent to the stems. They are at first broadly obovate, but soon become either subpyriform or irregularly globose and much wrinkled, and after having been exposed to a few showers they become quite amorphous, and form discoloured films on the leaves and branches. On the branches the sporiferous masses are very similar to those on the leaves, but they are rather larger and more irregular in shape. When young and dry, they often are reddish rather than brown, and lack the deep brown color generally seen in the early stages of other species. The mycelium is apparently perennial, but I am not entirely certain on that point.

The spores differ in several respects from those of the species already described. They are usually two-celled, but it is not at all unusual to find three cells, as is shown in Plate 2, fig. 25. They are broadly ovate, and attached to pedicels which, instead of being of nearly equal diameter throughout, as in the other species, are very much swollen just below the spores, in fact often more so than is shown in figs. 24 and 25. The breadth of the upper part of the pedicels, however, varies with the state of expansion of the sporiferous masses, being especially broad when they are young, and slenderer when they are old. The base of the spores where the pedicels are attached is very broad, and when the masses are quickly swollen, especially by means of re-agents, the inner portion of the pedicels expands more rapidly than the outer part, and the latter is ruptured just below the spore, so that there is left a hyaline ring surrounding the pedicel at the base of the spore.

The growth of the promycelia is peculiar in *G. clavipes*. As a rule the promycelia of the other species are given off from the cells near the part where they are in contact with one another, and they are either single or double, or, as is very frequently the case, four are given off at diametrically opposite points. Occasionally one sees a promycelium forming at the apex of the spore, and such a case, occurring in *G. macropus*, is shown in Pl. I, fig. 6. In *G. clavipes* it is very common for promycelia to be formed at the apex as shown in Pl. II, fig. 27, and another promycelium near the septum. The most peculiar form is that shown in fig. 26, where the spore has fallen from its pedicel, and a promycelium is produced both at the apex and the base. This form I have not found to be common, but it can be seen without difficulty.

The present species, in spite of some striking peculiarities, presents a general resemblance to *G. conicum*, which is common enough in Northern Europe, but is rare in this country, if indeed it occurs at all. *G. clavipes* was first separated from *G. conicum* in consequence of the swollen pedicels and the formation of promycelia at the apex observed by Peck. Curtis, judging from the specimens in his herbarium, did not distinguish *G. clavipes* from *Podisoma Juniperi* Lk. which is the same as the *G. fuscum* of the present article, for the specimen of Michener No. 4830, from Pennsylvania, and a specimen collected by Curtis himself at Hillsboro, N. C., certainly belong to *G. clavipes*. A second specimen from Society Hill, S. C., marked simply *Gymnosporangium*, also belongs to the present species. The question whether *G. clavipes* is merely a form of *G. conicum* or not, is not easily answered. The general appearance of the sporiferous masses is the same, and if the distortions produced are different, it may be said that that may be accounted for by the fact that in Europe *G. conicum* grows on *J. communis*, while what we call *G. clavipes* grows on *J. virginiana*. The swollen pedicels, even admitting that the amount of the swelling varies in different specimens, has not been noticed in European specimens of *G. conicum*, and, although Oersted figures one spore in which the promycelium is given off from the tip in *G. conicum*, it seems nearly certain that no European species has the apical form of germination, unless exceptionally. Taking these facts collectively, I should think that *G. clavipes* was a distinct species peculiar to America, and that it was not quite certain that the true *G. conicum* occurs with us. A few forms which can hardly be included in *G. clavipes*, I should refer to *G. conicum* with a doubt.

## GYMNOSPORANGIUM CONICUM, De Cand.

*Gymnosporangium conicum* D. C., Flore française, Vol. II, p. 216; Reess, loc. cit., p. 26.

*Gymnosporangium Juniperi* Lk., Obs. I, p. 9; Species Plantarum, Vol. VI, part 2, p. 127; Schweinitz, Syn. Fung. Am. Bor., No. 3094; Berkeley, Outlines, Pl. II, fig. 5; Curtis, Plants of North Carolina; Peck, in 25th Report; Frost, in Tuckerman's Cat. Amherst Plants.

*Gymnosporangium juniperinum* Fr., Syst. Myc., Vol. III, p. 506; Exsicc. Ravenel, Fungi Carol., Fasc. V, 87.

*Podisoma juniperinum* Oersted, Nouvelles Observations, 1866.

*Podisoma Gymnosporangium* Cooke, Notes on Podisoma, Pl. 18, fig. 2.

On *Juniperus communis*. Northern and Central Europe.

On *Juniperus virginiana*, Newton, Mass. (Farlow); New York State (Peck); South Carolina (Ravenel).

Sporiferous masses, subpyriform or indefinitely expanded, orange colored, half an inch high; spores oblong, two-celled, constricted at the septum,  $48\mu$ - $58\mu$  long, by  $15\mu$ - $18\mu$  broad; promycelia either two or four from each cell, given off near the septum. Mycelium perennial, forming long swellings in the branches.

As before said, the determination of American specimens of the present species is very unsatisfactory. The name *Gymnosporangium Juniperi* Lk., to be sure, often appears in catalogues of American fungi, but in many cases the determination is evidently doubtful, and I have not thought best to accept it in several cases, but have formed my opinion rather on specimens actually collected by myself or belonging to authentic collections. In most instances the species is said to occur on *Juniperus virginiana*. In Tuckerman's Catalogue of Amherst Plants, it is reported by Frost as growing on *J. communis*, but I have not been able to examine Frost's specimens, which probably belong to the true *G. conicum*. In the Bulletin of the Minnesota Academy of Sciences for 1876, the species is said to have been found on living branches of various trees, a statement which is probably inaccurate, and tends to make the determination doubtful. As far as my own experience goes, I have only once found a form which was probably to be referred to *G. conicum*, and, in that case, the fungus was in such a condition that an accurate determination was out of the question. Of all the specimens which I have examined, the No. 87, Fasc. V, of Ravenel's Fung. Carol., and two specimens in Herb. Curtis, collected by Ravenel on the Santee Canal in 1848 and 1850, come nearest to the true *G. conicum*. There is also a specimen in the Sprague collection which may belong to this species. Without larger sets of specimens in good condition one can not well say whether the specimens referred to may not belong to other species. Most specimens marked *G. Juniperi* Lk. which I have seen were gathered after the fungus had been exposed to the rain some time, and the only character by which one could be guided was the mode of germination of the spores, which, as I have said is generally that found in *G. clavipes*, and I am not sure that all the so-called *G. Juniperi* recorded on *J. virginiana* is not to be referred to *G. clavipes*. More material and further study are necessary to settle that point, and it is not impossible that some European botanist may discover that *G. conicum* has at times the same swollen pedicels and apical germination as *G. clavipes*. If that turns out to be

the case, our common *G. clavipes* must be regarded as a variety of *G. Juniperi*, but, as the matter now stands, I must believe that the two are distinct, and that the existence of *G. conicum* in the United States rests only on a few specimens resembling *G. clavipes* in habit, but which, as far as can be made out from specimens which as a whole are in poor condition, have longer and slenderer spores on pedicels which are not perceptibly thickened below the spores, and whose promycelia are in twos or fours near the septum.

#### ROESTELIA Rebent.

*Aecidium* usually hypophyllous, lower part sunk in the swollen tissues of the leaves, forming, above, cylindrical, conical, or oblong projections which are often split and fringed in the upper part, peridium composed of large, colorless cells, spores brownish or orange-colored, subglobose when mature, formed in moniliform rows. Spermogonia punctiform, forming minute dark-colored pustules in discolored spots on the upper surface of the leaves. Mycelium infesting the leaves and stems of different Pomeae.

The old genera *Aecidium*, *Roestelia*, and *Peridermium* cannot be distinguished from one another except in an arbitrary way. The species of *Peridermium* are parasitic on different Coniferae, the *Roesteliae* on species of Pomeae, and *Aecidium* proper is very widely diffused. Wolff<sup>1</sup> considers that *Peridermium Pini* is the aecidial form of *Coleosporium Senecionis*, and De Bary and Hartig have connected other *Peridermia* with *Chrysomyxa* and *Calyptospora*. The *Roesteliae* differ from the species of *Aecidium* in the fact that the peridium is elongated in a more or less tubular form, whereas in *Aecidium* it is short. But in forms like *R. penicillata* (Sow.) the peridium is comparatively short, while in *Aecidium Fraxini* Schw. the peridium is so long that in the Syn. Fung. Am. Bor. it was placed by Schweinitz in *Roestelia*. In his work, *Untersuchungen über die Brandpilze*, De Bary considered it to be a distinguishing mark of *Roestelia* that the spores were not formed from all the cells of the sporiferous filaments but from every other cell, so that the spores hung together for a short time by the shrivelled sterile cells. Reess adopts the same view, but more recently De Bary<sup>2</sup> has stated that similar sterile cells are found in other genera than *Roestelia* and they are certainly found in *Caeoma luminata* Schw. and in species of *Aecidium* which I have examined. The cells which form the peridium are, like those found in *Aecidium*, large and colorless, with thick walls which generally have peculiar markings. They are only loosely adherent, and although they may cohere to one another in longitudinal rows, the rows, especially at the upper end of the peridium, soon separate from one another and form a fringed mouth to the peridium. In some species, however, the cells at the apex remain united and those below separate from one another so as to form a sort of lattice-work, through the meshes of which the spores escape.

The spores of *Roestelia* are more or less angular, when young, from mutual pressure, but when mature they generally become globose. They are almost always of a brownish color, but in one of our species they are orange-colored. The wall of the spores is double, consisting of a rather thick endospore and a thin exospore. The endospore is perforated

<sup>1</sup> Beitrag zur Kenntniss der Schmarotzerpilze, Landwirthsch. Jahrb., 1877. <sup>2</sup> Bot. Zeit., 1869, p. 786.

with a number of holes, usually from five to ten, and it is through these holes that the germinial tubes protrude. Reess considers that the number of pores can be used as a means of distinguishing species, but my experience shows that the number is variable in the same species. The spermogonia are small and found in clusters in discolored spots on the upper surface of the leaves, where they are seen as brownish black dots. The spermatia are punctiform and are almost identical in all the species of the genus.

The Roesteliae are very abundant on the leaves of our different thorns and fruit trees, and they are also found on the fruit. In some cases they cause distortions of the stems, which swell to twice their original size and become cracked and very irregular, or, if the stems attacked are small and flexible they often become much recurved. The presence of members of this genus in the leaves is indicated by yellowish or reddish spots in which the spermogonia appear first on the upper surface, while the aecidia do not become visible until after a considerable interval in most cases. The amount of swelling produced in the leaves by the aecidia varies much in the different species. In some it is only slight, often in the form of a ring, but in others prominent ovoid or conical projections are found. The duration of the mycelium is a point of importance in considering the connection between Roestelia and Gymnosporangium. Certainly in some cases it seems to be perennial, but supposing that there is a genetic connection between the two genera just named, one would expect the Roesteliae to be annual products of the germinating sporidia of the different Gymnosporangia. The date of the appearance of the different species is also of importance in attempting to connect any particular Roestelia with a given species of Gymnosporangium. Some species, as *R. penicillata*, mature in May and June, almost simultaneously with the Gymnosporangia, while other species, as *R. botryapites*, do not ripen until the middle of September or October. From an economical point of view, the Roesteliae are of considerable importance, since they attack the leaves of so many of our fruit trees, causing them to fall prematurely, and some of the species attack the young fruit as well as the leaves.

The determination of the species from their anatomical structure is attended with many difficulties. The principal characters used are the gross appearance of the spots and swellings and the microscopic characters of the spores and the cells of the peridium. Too many species depend upon the amount of splitting of the peridium which evidently must depend to a large extent upon the age of the latter and accidental circumstances. The species of Roestelia are, moreover, not limited to a single host-plant, and one must naturally expect modifications of the swellings and of the peridium according as the Roestelia is parasitic on different hosts.

#### ROESTELIA BOTRYAPITES Schw.

*Caeoma (Roestelia) botryapites* Schweinitz, Syn. Fung. Am. Bor., No. 2902.

*Roestelia Ellisii* Peck, Bull. Torrey Club, Vol. vii, p. 13. Exsicc. Mycoth. Univers., No. 431.

*Roestelia botryapites* Schw., Berkeley in Grevillea, Vol. v, p. 34; Farlow, Bull. Bussey Inst., Vol. ii, p. 225.

Aecidia hypophyllous, borne in tuberculated or pyriform protuberances about an eighth of an inch high, sometimes solitary, usually densely aggregated or consolidated, 3-14,

usually 7-8 together; peridia cylindrical, contracted at the base, brownish-white, an eighth of an inch long, composed throughout of long, sinuous, smooth-walled cells,  $12\mu$ - $15\mu$  in diameter, which cohere at the apex and separate below in meshes so that the peridium is clathrate. Spores brownish,  $15\mu$ - $19\mu$  in diameter, episporule slightly granular, pores indistinct. Spermogonia few in number in the depressed upper part of the leaves.

On the leaves of *Amelanchier canadensis*.

Eastern Massachusetts (Farlow); Newfield, N. J. (Ellis); Bethlehem, Pa. (Schweinitz).

A striking species which does not mature until the middle of September or the first of October, the spermogonia appearing in the latter part of August. It is distinguished from our other species by the large-sized tubercles which appear in dense clusters on the under surfaces of the leaves, from which protrude the long peridia which resemble those of *R. cancellata* in having the cells coherent at the apex and separate below, so that the peridium becomes clathrate, the spores being discharged through the meshes. The peridia, however, are less broad and bulging than in *R. cancellata* and the microscopic character of the cells is very different. In *R. botryapites* they are longer and more slender than in any of our other species, and the cell-walls are destitute of the papillose or granular markings found in most of the species. They are also so sinuous and so long that an accurate measurement of their length is out of the question. The different cells, instead of overlapping at the extremities as in *R. cancellata*, fit closely together, and the apical cells, instead of being shorter and broader than those below as in the species last named, are of about the same breadth and shape throughout. In fact, so narrow and smooth are the cells and so closely are they united to one another at the extremities that, on seeing them for the first time under the microscope, one would be more likely to suppose them to be some brownish mycelium than a collection of peridial cells. The spores of *R. botryapites* are, on the average, smaller than those of our other species. The fungus forms reddish-yellow spots on the leaves of Amelanchier in which the spermogonia are developed in comparatively small numbers, and when the swollen masses of the leaf in which the aecidia are borne appear, the upper surface bearing the spermogonia becomes depressed. The tubercular masses are much contracted at the base, and when fully mature they drop from the leaves, only a small scar remaining. The cells of the tubercles abound in starch grains, in this respect resembling *R. cancellata*.

The present species is very common in Eastern Massachusetts and has probably a wider range than one would infer from the very few recorded localities. It is frequently seen in entomological collections, and the large tubercles with their small bases certainly remind one more strongly of insect galls than the work of fungi, at least until the peridia have protruded. The Schweinitzian species remained for a long time obscure, but it was rediscovered by Ellis at Newfield, N. J., and named by Peck *G. Ellisii*. Berkeley is quoted in Grevillea, loc. cit., as having ascertained the identity of the two species from the examination of an original specimen of Schweinitz. There is a specimen from Schweinitz in Herb. Curtis, but the peridia and spores are not mature. As far, however, as can be judged from its present condition, it seems to be the same as specimens collected by Ellis.

## ROESTELIA TRANSFORMANS Ellis.

*Roestelia transformans* Ellis, Bull. Torrey Club, Vol. v, p. 3; Farlow, Bull. Bussey Inst., Vol. ii, p. 255. Exsicc. Thümen, Mycoth. Univers., No. 1029.

Aecidia hypophyllous, or covering the young shoots and fruit, borne in conical protuberances, occasionally 3-4, generally 5-20 or more together, consolidated at the base; peridium brownish-yellow, a tenth to a twelfth of an inch long, at first conical but soon becoming lacerated; cells of peridium isodiametric at apex, below long and narrow,  $12\mu$ - $15\mu$  in diameter, not overlapping on the inner side, cell-wall papillose; spores globose, brownish,  $18\mu$ - $22\mu$  in diameter, cell-wall nearly smooth. Spermogonia few in number in purplish-red spots on the upper side of the leaves.

On the leaves, fruit and young shoots of *Pyrus arbutifolia* and on the leaves of *Pyrus malus*.

Newfield, N. J. (Ellis); Newton, Gloucester, Wood's Holl, Mass. (Farlow).

This species, which occupies an intermediate position between *R. botryapites* and *R. cancellata*, is common on *Pyrus arbutifolia* in Eastern Massachusetts. It occurs in three forms. On the leaves it forms purplish-red spots and the aecidia are generally comparatively few in number and rather slender. On the fruit they are more numerous and shorter, and when the fungus is found on the young shoots they swell to several times their original size, and become much curved and twisted and take on a yellow color. The number of aecidia produced on the stems is very large. The aecidial protuberances are rather acutely conical and more slender than in either *R. botryapites* or *R. cancellata*; they readily fall from the leaves as in the first-named species. It is only in the young condition that the cells of the peridia cohere at the apex, and, as generally seen, the peridia are lacerate. The peridial cells resemble those of *R. cancellata* but are more slender and do not project inwards. The spores resemble those of *R. botryapites*.

What seems to me the same species was collected on apple leaves near the Bussey Institution, Jamaica Plain, Mass., but did not seem to be common. The species is probably common near the sea-shore, but is actually recorded in but few places. It is not likely to escape observation wherever it occurs for the purple spots on the leaves and the distorted shoots are very striking.

## ROESTELIA CANCELLOATA Rebent.

*Roestelia cancellata* Rebent, Fl. Neom., p. 350, Pl. II, fig. 9; Curtis, List of Plants of North Carolina, p. 123; Oersted, Om en saeregen, etc., Pl. II and III; Reess, loc. cit., p. 20; Decades of Maine Fungi, p. 180; Grevillea, Vol. v, p. 151.

*Aecidium cancellatum* Schweinitz, Syn. Fung. Carol., No. 433.

*Caeoma roestelites* Lk., Spec. Plant., Vol. vi, part 2, p. 164; Schweinitz, Syn. Fung. Am. Bor., No. 2900.

Aecidia usually hypophyllous, borne in the swollen tuberculated substance of the leaves, consolidated at the base in clusters of 4-20; peridia yellowish-white, a twelfth to an eighth

of an inch long, broadly ovate, acute and closed at the apex, clathrate below; peridial cells thick-walled, surface papillose, isodiametric, about  $38\mu$ , coherent at the apex of peridium, below united in longitudinal rows; cells about  $20\mu$  thick by  $60\mu$ - $80\mu$  long, the upper end of each cell projecting inwards and overlapping the base of the cell above; spores brownish, roundish-angular,  $25\mu$  to  $30\mu$  in diameter, cell wall thick, pores well marked. Spermogonia numerous in the discolored upper surface of the leaves.

On leaves of apple and pear trees.

Westbrook, Me. (Bolles); Bethlehem, Pa. (Schweinitz); North Carolina (Curtis); California (Harkness). Europe.

The typical *R. cancellata* is common in Europe and is easily distinguished. It has been published in several series of exsiccati of which I need only mention Libert, No. 394, and Thümen, Mycoth. Univers., No. 537, where the specimens are very characteristic. The aecidia are borne in swollen parts of the under surface of the leaves, but the swellings are by no means so large as those of *R. botryapites* and they are broad at the base, not constricted as in the last-named species. Although the peridium bears some resemblance to that of *R. botryapites* and *R. transformans*, it is distinct in having the upper end of the cells prolonged inwards in the form of a papilla. The peridial cells are quite different from those of *R. botryapites* but resemble more closely those of *R. transformans*. *R. cancellata* must be considered a rare species in the United States as far as at present known. It is only known in doubtful cases in Eastern Massachusetts and it is not enumerated by Peck among the Roesteliae of New York. The fungus mentioned under the name of *R. cancellata* in Bull. Bussey Inst., Vol. II, p. 225, does not seem to me really to be that species. The only specimens which I have examined of the *Aecidium cancellatum* of the Syn. Fung. Car. Sup. and of *Caeoma roestelites* Syn. Fung. Am. Bor., were in poor condition, and certainly were not typical *R. cancellata*, and although mentioned in Curtis's list as occurring in North Carolina, there are no specimens in Herb. Curtis to mark the locality. Considering that the species is easily recognized from European specimens, there would probably be no difficulty in recognizing it if it occurred with us. One thing is certain, that the very common Roestelia found on apples in the autumn in Eastern Massachusetts is not *R. cancellata*. The present species is generally found on the leaves only, but is said also to attack the smaller branches.

#### ROESTELIA CORNUTA (Ehrh.) Fr.

*Aecidium cornutum* Pers. in Gmel. Syst. Nat.

*Caeoma cylindrites* Link, Species Plantarum, Vol. VI, part 2, p. 64, in part; Schweinitz in Syn. Fung. Am. Bor., in part?

*Roestelia cornuta* Fr., Summa Veget. Scand., Vol. II, p. 510; Oersted, Nouvelles Observ., Pl. IV; Reess, loc. cit., p. 28; Peck, 24th Report; Farlow, Bull. Bussey Inst., Vol. II, p. 225; Tuckerman's Plants of Amherst.

*Ceratitium cornutum* Rabenh., Bot. Zeit., 1851, 452.

*Centridium* sp. Chevallier, Desmazières, et al.

Aecidia hypophyllous, in pulvinate, orange-colored thickenings of the leaves, densely agglomerated, 10-40 together, often arranged in a circle; peridia yellowish-brown, cylindrical-acute, recurved, generally entire but when old becoming fimbriate; peridial cells large, polygonal, coherent throughout, thick-walled,  $38\mu$ - $15\mu$  broad by  $58\mu$ - $76\mu$  long; spores yellowish brown, surface slightly papillose, roundish-angular,  $18\mu$ - $22\mu$  in diameter; spermogonia numerous in reddish-yellow spots on the surface of the leaves.

On the leaves of *Pyrus americana*, *Amelanchier canadensis*, *Crataegus* sp.

Eastport, Maine (Farlow); Amherst, Mass. (Frost); New York (Peck); Ithaca, N. Y. (Dudley). Northern and Central Europe.

This species in its typical form is common on the leaves of *Pyrus americana* at Eastport. The spots on the leaves are of a brilliant reddish-yellow color, the spermogonia very numerous and the aecidia crowded together in a circle, the swelling of the leaf being in the form of a circular elevation and not at all tubercular as in the preceding species. The peridia are long and recurved and preserve their shape for a considerable time, becoming at length lacerate. In this, its typical form, it is more robust than *R. lacerata*, and the peridial cells are broader and thicker. The form which occurs on *Amelanchier* has fewer aecidia in a cluster, the substance of the leaf around their bases is more distinctly tubercular, and the peridia are shorter and more acute than in the form on the mountain ash, approaching, perhaps, *R. lacerata*. The occurrence of *R. cornuta* on species of *Crataegus* in the United States possibly requires confirmation. I have specimens on *C. crus-galli* which may perhaps be referred to *R. cornuta* but am not certain. None of the Schweinitzian specimens of *Caeoma cylindrites* which I have examined seem to belong to the present species, but possibly some of the varieties mentioned under that head in the *Syn. Fung. Am. Bor.* may be placed here.

#### ROESTELIA LACERATA (Sow.) Fr.

*Aecidium oxyacanthae* Pers., *Syn.*, 206.

*Aecidium Mespili* and *oxyacanthae* D.C., *Flore française*, Vol. vi, p. 98.

*Aecidium laceratum* Sow., *British Fungi*, Pl. 318. *Exsicc. Ravenel, Fungi Carol.*, Fasc. v, 96.

*Aecidium crataegi* var. *oxyacanthae* Schweinitz, *Syn. Fung. Car. Sup.*, No. 432.

*Caeoma cylindrites* var. *Crataegi punctatae*, var. *arborescentis* and var. *C. oxyacanthae* Schweinitz, *Syn. Fung. Am. Bor.*, No. 2899.

*Roestelia lacerata* Fr., *Summa Veget. Scand.*, Vol. ii, p. 510; *Sprague, Contrib. to New England Mycol.*, p. 329; *Decades of Maine Fungi*, p. 180; Peck, 22d and 24th Reports; Farlow, *Bull. Bussey Inst.*, Vol. ii, p. 255; Tuckerman, *Plants of Amherst*; Harkness and Moore.

Aecidia hypophyllous, sometimes on the stems and young fruit, seated on the yellow pulvinate thickening of the leaves, slender, cylindrical or somewhat subulate, recurved, densely clustered, 5-30 together; peridia yellowish-white, rather delicate, soon splitting and becoming fimbriate, the divisions not extending to the base of peridium; cells of peridium narrow,  $20\mu$  broad by  $55\mu$ - $75\mu$  long; spores brownish, roundish-oblong, surface

finely granulated,  $19\mu$ - $24\mu$  in diameter. Spermogonia in yellowish spots on the upper surface of the leaves.

On leaves, stems, and fruit of *Crataegus crus-galli*, *C. punctata*, *C. coccinea*, *C. tomentosa*, *C. oxyacantha*, and other species; on leaves and fruit of *Amelanchier canadensis*, and on leaves of wild and cultivated apples.

Common from Maine (Bolles) to South Carolina (Mellichamp), and west to Missouri (Engelmann).

This is decidedly the most common species found with us, and it abounds on all wild and cultivated species of *Crataegus* and apples. On the one hand the species approaches *R. cornuta*, from which it is distinguished by being more slender, and when young, splitting into segments which become fimbriate, and by the narrower peridial cells. On the other hand, it approaches *R. penicillata* with which, in fact, it is united by some authors. *R. lacerata* is more variable than most of our species, and I can distinguish the following forms. On *C. tomentosa* and other species of *Crataegus* the aecidia are borne on small, slightly swollen spots, and the peridia are large and diverge from one another. Our form is precisely the No. 556 of Westendorp and Wallys. The form on *Amelanchier* is the *Aecidium Mespili* D.C., and the swellings of the leaves are more strongly marked, and the peridia shorter than in the form last described. Our smallest form is found on apple leaves. The spots are bright yellow and the aecidia are few in number, often only 1-3, and occupy the centre of the spot. Possibly this last form might be separated as a distinct species. It is, apparently, not the variety *Mali* of the Syn. Fung. Am. Bor. The specimen in *Mycotheca Universalis*, No. 732, collected by Ellis at Newfield, N. J., labelled *R. lacerata*, f. *Mali*, is said by Von Thümen to be synonymous with *Aecidium cancellatum* of the Syn. Fung. Carol. Sup., but on what authority the statement rests is uncertain.

#### ROESTELIA PENICILLATA (Sow.) Fr.

*Aecidium penicillatum* Pers., in Gmel. Syst.

*Aecidium Mali* Schum., Fl. Saell., Vol. II, 222.

*Aecidium laceratum* D. C., Flore Française, Vol. VI, p. 98.

*Caeoma cylindrites*, var. *Mali* Schweinitz, Syn. Fung. Am. Bor., No. 2899.

*Aecidium pyratum* Schweinitz, Syn. Fung. Am. Bor., No. 2896.

*Roestelia penicillata* (Sow.) Fr., Summa Veget. Scand., Vol. II, p. 510.

*Ceratitium penicillatum* Röbénh., Bot. Zeit., 1851. 452.

On leaves and fruit of *Pyrus malus* and *Pyrus angustifolia* and fruit of *Amelanchier canadensis*.

Eastern Massachusetts (Farlow); Santee Canal, S. C. (Ravenel).

Same as *P. lacerata*, but aecidia smaller and frequently concentrically arranged, peridia splitting to the base, the divisions very numerous, revolute, fimbriate, formed of one or more rows of cells.

The present species, if indeed it is not a form of the one last described, does not appear in American Catalogues as distinct from *R. lacerata*. It is not uncommon and seems to

attack the fruit more frequently than *R. lacerata*. The *Aecidium pyratum* of Schweinitz, Syn. Fung. Am. Bor., is probably the same as *R. penicillata*. I am indebted to the officers of the Academy of Natural Sciences of Philadelphia for the privilege of examining the original specimen in their collection and I have also specimens from Ravenel and Curtis which do not differ from the type. Although it is unusual to find *R. penicillata* on Crataegus in this country, what seems undoubtedly that species was collected by Prof. W. R. Dudley on *C. crus-galli* at Ithaca, New York.

#### ROESTELIA HYALINA Cooke.

*Roestelia hyalina* Cooke, in Bull. Bot. Soc., 1877, pp. 314, 315; Hedwigia, Vol. xvii, p. 38; Grevillea, Vol. vi, p. 137. Exsiccati. Ravenel, Fungi Americani, No. 37.

Aecidia hypophyllous, borne few together in subpyriform tubercles; peridia pointed, cylindrical, delicate, splitting longitudinally; peridial cells rhombic-ovate, about  $35\mu$  broad by  $55\mu$  long, cell-walls thin, nearly smooth; spores globose,  $19\mu$ - $22\mu$  in diameter. Spermogonia few, in yellowish spots on the upper surface of the leaves.

On leaves of Crataegus.

Aiken, S. C. (Ravenel).

This species is only known to me by the single small specimen in the Fungi Americani Exsiccati, from which the description above given was taken. The specimen bears a close resemblance to some forms of *R. lacerata*, but the cells of the peridium are thin walled and destitute of the markings generally seen in the other species. The spores in my specimen are distinctly brownish and not orange colored as given in the description in Hedwigia, loc. cit. As it may be that there was an error in distribution, I quote the original description. "Epiphylla, vel amphigena. Maculis rufis. Soris convexis brunneis. Pseudoperidis cylindrico-acuminatis, longitudinaliter et unilateraliter dehiscentibus. Sporis globosis, aurantiacis, .02-.022 mm."

#### ROESTELIA AURANTIACA Peck.

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*Roestelia aurantiaca* Peck, in 25th Report, p. 64, Pl. 1, figs. 10-12; Bull. Buffalo Soc. Nat. Sci., Vol. 1, p. 68; Tuckerman's Plants of Amherst; Farlow, Bull. Bussey Inst., Vol. II, p. 225. Exsiccati. Ravenel's Fungi Americani, No. 2N 2/

*Roestelia lacerata* Herb. Curtis in part.

Aecidia densely aggregated on the young fruit and swollen stems; peridia erect or slightly recurved, an eighth to a quarter of an inch in length, cylindrical, tubular, shining white, coarsely toothed at the apex, teeth seldom extending more than a quarter of the length of the peridium; cells of peridium squarish-ovate, closely united, about  $55\mu$  long by  $36\mu$  broad, cell wall very thick and striate. Spores bright orange, spherical or slightly angular,  $27\mu$  to  $47\mu$  in diameter, average  $30\mu$ - $40\mu$ , cell wall thick, punctate, pores distinct. Spermogonia in discolored spots on the leaves.

On unripe fruit and stems of *Crataegus crus-galli*, *C. punctata*, *C. oxyacantha* and other species of Crataegus, on *Amelanchier canadensis* and on cultivated quinces and apples.

Not rare from Massachusetts (Farlow), Vermont (Frost), New York (Peck), to North Carolina (Curtis), South Carolina (Ravenel), and Missouri (Engelmann).

By far the most beautiful species of the genus which we have, at once attracting the popular eye by its brilliant orange or almost cinnabar colored spores and shining white peridium. It is generally found on the young fruit, though it is occasionally found on the stems and petioles, but I do not recollect having seen aecidia on the leaves. What I take to be spermogonia of this species are found on the leaves apart from the aecidia. *R. aurantiaca* is often accompanied by *R. lacerata*, but one cannot consider the former to be a form of the latter, which grows on the fruit rather than leaves, for the differences in the spores and cells of the peridium are too marked to warrant any such supposition. The peridia of the present species are more rigid than those of our other species, and the cells cohere throughout, except at the tip where the peridium splits into comparatively few short teeth, and does not become lacerate or penicillate as in most of the species. The spores are large for the genus Roestelia, and instead of the brownish tinge common in other species, they are bright orange. The cell-wall is quite thick and striate. In drying, the spores become pale, but their size and cell-wall even then are sufficient to distinguish present from other species.

*R. aurantiaca* is represented in Herb. Curtis by several specimens, including some collected by himself in North Carolina. He apparently considered them all forms of *R. lacerata*, at least, they are so labelled. The species is particularly apt to attack the different species of Crataegus, and the peridia attain a large size on the small berries of that genus. It is reported by Peck to occur on Amelanchier, but I have never myself seen it on that host. Perhaps the most striking form is that which is often found on quinces in Eastern Massachusetts. I have collected specimens in Newton and I have received others from Pepperell, Miss Freeman; and from near Salem, Mr. Robinson; and there are specimens in Herb. Curtis and the Sprague collection from Mr. John Russell. One sometimes sees a quince two inches in diameter more than half covered by the bright orange aecidia and occasionally small apples are affected in a similar way. *R. aurantiaca* is generally found in midsummer, I have, however, seen it on *C. crus-galli* as late as October.

After the preceding detailed account of the species of Gymnosporangium and Roestelia of the United States, one naturally wishes to know how far the view first promulgated by Oersted is confirmed by cultures made with American species. Oersted recognized three species of Gymnosporangium, and, at first, four species of Roestelia growing in Denmark. He was afterwards induced to believe that two of the supposed Roesteliae, *R. lacerata* and *R. penicillata*, were only forms of a single species, and he considered that he had proved that *G. fuscum* was connected with *R. cancellata*; *G. clavariaeforme* with *R. lacerata*, including in that the form *R. penicillata*; and *G. conicum* with *R. cornuta*. Thus, there were no superfluous species of either genus in Denmark, that is, there was no species of one genus which could not be matched with a species of the other genus.

From the account already given, it will be seen that I recognize the following species, and the question which I have unsuccessfully tried to answer is, what species with us are genetically connected. To sum up the species, we have:

GYMNOспорANGIUM.	ROESTELIA.
<i>G. Ellisii.</i>	<i>R. botryapites.</i>
<i>G. clavariaeforme.</i>	<i>R. transformans.</i>
<i>G. macropus.</i>	<i>R. cancellata.</i>
<i>G. fuscum.</i>	<i>R. cornuta.</i>
<i>G. fuscum</i> var. <i>globosum.</i>	<i>R. lacerta.</i>
<i>G. biseptatum.</i>	<i>R. penicillata.</i>
<i>G. clavipes.</i>	<i>R. hyalina.</i>
<i>G. conicum?</i>	<i>R. aurantiaca.</i>

It will be seen that I have mentioned eight species of each genus which could on anatomical grounds alone be considered distinct. Of the species enumerated, *G. conicum* is given as doubtful, because it seemed to me that sufficiently abundant material was wanting to enable any one to speak with certainty. *G. fuscum* var. *globosum*, it will also be borne in mind, is not by several writers considered distinct. With the possible exception of the two species just mentioned, the validity of the species of Gymnosporangium is not likely to be much questioned. Turning to the Roesteliae, we have *R. lacerata* and *R. penicillata* enumerated, which are by many writers united on anatomical grounds, apart from any developmental considerations, and *R. cancellata*, a species whose presence, or, perhaps better, whose distribution in the United States is not sufficiently well known in my opinion. In speaking of *R. lacerata*, also, one must not forget that, even in the limited sense in which I have adopted it, it appears under a good many different forms which some botanists on anatomical grounds alone might consider distinct.

If one is disposed to admit the eight species of each genus with the limitations I have given, he might suppose that the task of tracing the connection between them would be comparatively simple and interesting. A very slight experience, however, would convince him of the contrary. In the first place, if we accept the conclusions of Oersted as correct with regard to the Danish species, knowing that two and perhaps all three of the Danish Gymnosporangia are found in the United States, we are struck with the fact that, although *G. fuscum*, regarding var. *globosum* as distinct, and the true *R. cancellata*, its supposed aecidial form, are about equally common, or rather equally rare, with us, when we come to *G. clavariaeforme*, the case is different, for the Gymnosporangium is not at all common, while its presumed aecidium, *R. lacerata*, is very common, indeed being found hundreds and even a thousand miles from localities where *G. clavariaeforme* is known. About the comparative distribution of *G. conicum*, and its corresponding *R. cornuta*, little can at present be said, since the localities of *G. conicum* are not well known. Yet, in general, what is supposed to be *G. conicum* is best known towards the South, while *R. cornuta* is northern in its range, unless, indeed, that species properly includes some of the forms now included in *R. lacerata*. If, on the other hand, with some writers we regard the var. *globosum* as identical with *G. fuscum* of Europe we are, in looking at the distribution, met with the difficulty that *G. fuscum* var. *globosum* is very common in Massachusetts, for instance, whereas its supposed aecidium, *R. cancellata*, is not known with

certainty to occur at all, and where, at least, the common Roestelia on apple leaves is certainly not *R. cancellata*.

At first sight, then, we would not admit the correctness of Oersted's views with regard to particular species without further inquiry, and one naturally resorts to artificial cultures. These may consist in sowing the germinating sporidia of the different species of Gymnosporangium either on leaves of different Pomeae, kept moist under bell-glasses, or on the young plants themselves. The former mode is more convenient, but has this objection that, although after sowing sporidia on the leaves spermogonia may appear in from about eight days to a fortnight, yet the interval is so great between the production of spermogonia and the development of the aecidia, from which alone the species can be with certainty determined, that the leaves, kept in a moist place, are almost sure to be destroyed by moulds before the aecidia have developed. Cultures made with the young plants themselves permit the development of the aecidia, but for mechanical reasons they are less easy to manage, and one is also obliged to keep a series of plants on which no sowing has been made, in order to make it comparatively sure that the mycelium of the Roestelia was not in the plants before the cultures began. I have, as a rule, made use of leaves only because the amount of space at my control was limited, and because it was difficult for me to procure young plants of some of the species required for cultures. The season of the year when the subject must necessarily be studied, the latter part of the spring, is, moreover, one when numerous occupations prevent my devoting as much of my time to the cultures as I should like.

In the spring of 1875, I procured two plants of *Amelanchier canadensis* about a foot high, and sowed upon the leaves the sporidia of *G. macropus* which were seen by microscopic examination to be in good condition. Nothing resulted from it. I was led to begin with this experiment because the most striking Gymnosporangium in the region of Boston is *G. macropus*, and one of the most prominent Roesteliae is *R. botryapites* which grows only on Amelanchier, and both species are peculiar to America. Since 1875 I have repeatedly made attempts by cultures to demonstrate the connection between our different species. The species with which I have experimented are *G. macropus*, *G. fuscum* var. *globosum*,<sup>1</sup> *G. Ellisii*, *G. biseptatum*, and *G. clavipes*, all common near Boston.

### I. May, 1876.

*G. clavipes* sown on 6 Amelanchier leaves. No result.

*G. Ellisii* on 6 apple leaves, three Amelanchier leaves, and two leaves of *Crataegus tomentosa*. No result.

*G. macropus* on 3 leaves of *Crataegus tomentosa*, 6 apple leaves, 4 Amelanchier leaves. Spermogonia formed on one leaf of *C. tomentosa*.

*G. globosum* on 3 leaves of *Crataegus tomentosa*, 3 of Amelanchier, and 3 of apple. Spermogonia appeared on all the leaves of Crataegus.

### II. May, 1876.

*G. macropus* on two small pear seedlings. No result.

*G. globosum* on one young plant of *Crataegus oxyacantha*. No result.

### III. June, 1876.

*G. globosum* on 5 leaves of *Crataegus tomentosa*. No result.

*G. macropus* on 3 leaves of Amelanchier. No result.

<sup>1</sup> For sake of brevity this form is given under the name of *G. globosum* in the following tables.

*G. clavipes* on 3 leaves of Amelanchier. No result.

NOTE. The cultures of 1876 were made at the laboratory of the Bussey Institution. Those made in June continued only 17 days, but no result being then obtained the laboratory was closed for the season.

#### IV. May, 1877.

*G. macropus* on 3 leaves of apple, 3 of Amelanchier, 3 of *Crataegus tomentosa*, and 3 of *Pyrus arbutifolia*. Spermogonia appeared on one leaf of Amelanchier and one of *C. tomentosa* in ten days.

*G. globosum* on 3 leaves of apple, 3 of Amelanchier, 3 of *Crataegus tomentosa*, and 3 of *Pyrus arbutifolia*. Spermogonia appeared on all the leaves of Crataegus.

*G. biseptatum* on 3 leaves of *Crataegus tomentosa*, 3 of apple, 3 of Amelanchier, and 3 of *Pyrus arbutifolia*. Spermogonia appeared on one leaf of Crataegus in six days.

*G. Ellisii* on 3 leaves of apple and 3 of Amelanchier. No result.

NOTE. The cultures of 1877 were made at the Bussey Institution, and lasted from May 25th to July 4th.

#### V. June, 1878.

*G. macropus* on 3 apple leaves, 3 of *Crataegus oxyacantha*, 3 of *C. crus-galli*, and 3 of pear. No result.

*G. Ellisii* on 3 apple, 3 pear, 3 *C. oxyacantha* and 3 *C. crus-galli* leaves. No result.

*G. biseptatum* on 3 apple, 3 pear, 3 *C. oxyacantha* and 3 *C. crus-galli* leaves. No result.

*G. globosum* on 3 pear, 3 *C. oxyacantha*, 3 *C. crus-galli*, and 1 apple leaf. No result.

#### VI.

*G. Ellisii* on two pear seedlings and on two young plants of *C. tomentosa*. No result.

*G. macropus* on an apple seedling and 2 plants of *C. tomentosa*. No result.

Being absent from Cambridge in 1879, no cultures were made, and the cultures of 1880 present no result worth detailing, as no spermogonia were produced.

In reviewing the record given above, one is struck with the small number of cases in which spermogonia succeeded the sowings on the different Pomeae. Certainly a sufficient variety of leaves was selected, for it is on Amelanchier, Crataegus, *Pyrus arbutifolia*, and cultivated apples and pears that the greater part of our Roesteliae are found in nature. That the sporidia used were in good condition was shown by microscopical examination. In running over the list, it is seen that the only plants on which spermogonia were produced were *Crataegus tomentosa* and *Amelanchier canadensis*. Those on Amelanchier followed the sowing of the spores of *G. macropus*, but, inasmuch as three species of Roes-telia are known on that plant, it is impossible to say to which the spermogonia belonged. What is surprising, however, is that of the three species of Gymnosporangium which were followed by spermogonia on *C. tomentosa*, viz.: *G. macropus*, *G. globosum*, and *G. biseptatum*, not one is the species which, according to Oersted, ought to produce our common form on *C. tomentosa*, namely *R. lacerata*. Accepting his view one would hardly have been led to expect spermogonia on such a host plant from three species so distinct from *G. clavariaeforme*. Further, we are not allowed to suppose that the production of spermogonia on *C. tomentosa* indicates any close resemblance between the three different Gymnosporangia. It might, perhaps, be said, considering how much more frequently the spermogonia followed the sowing of *G. globosum* than of the other two species, that where the spermogonia appeared to follow the latter, it was really because some of the

sporidia of *G. globosum* had become mixed with those of the two other species. Such a supposition is possible in the case of *G. macropus* which often grows in company with *G. globosum*, but it can hardly be true of the *G. biseptatum* in question, which grew in a deep swamp remote from *G. globosum*, and the specimens of which were collected and covered with care to prevent a mixing of the spores with those of other species.

Whether we consider the distribution of our species or the results of the cultures made, there is nothing to confirm the views of Oersted as to the connection of particular species. In this connection, I would refer to a paper by Ráthay known to me only by the abstract given by Magnus in Bot. Zeit., 1880, p. 798. The method of culture adopted by Ráthay is unknown to me, but he came to the conclusion that *R. penicillata* belonged not as a form of *R. lacerata* to *G. clavariaeforme*, but to *G. fuscum*. If then our *G. fuscum* var. *globosum* be really a variety of *G. fuscum*, and if *R. penicillata* be a form of *R. cancellata* as supposed by Ráthay, then the spermogonia on *C. tomentosa*, which so frequently followed the sowing of the sporidia of *G. globosum*, might be supposed to belong to what I have called *R. penicillata*, which does occur on Crataegus in the United States. One could not be at all certain, however, without seeing the fully developed aecidia, but it must not be forgotten that those who are fully imbued with the belief that the different aecidial genera as Aecidium, Roestelia, etc., are stages of Puccinia, Gymnosporangium, etc., accept the appearance of spermogonia alone, without having seen the aecidia, as strong proof of a connection between different forms. In fact the instances where the aecidia themselves have been produced by cultures of teleutospore forms are very few in number. But even if we admit that the spermogonia following the sowing of *G. fuscum* belonged to *R. penicillata*, what are we to say of those which followed the sowing of *G. macropus* and *G. biseptatum*? It is absolutely impossible to consider *G. biseptatum* a form of *G. fuscum*, nor, in my opinion, is there any reason to suppose that *G. macropus* is a form of that species.

Spermogonia followed sowings of *G. macropus* on both *C. tomentosa* and Amelanchier, and accordingly they might have belonged to *R. lacerata* or *R. aurantiaca*. *R. cornuta* may be excluded as belonging, according to Oersted, to *G. conicum*, which is not in the least related to *G. macropus*, and the distribution of *R. hyalina* makes it very improbable that it is connected with the ubiquitous *G. macropus*. *R. lacerata* should be connected with *G. clavariaeforme* and, as has already been remarked, Schroeter has suspected that *G. macropus* may be a form of the last named species, but I have already stated my reasons on structural grounds for not considering them two forms of the same species, and I do not think that that belief should be altered in consequence of the results of my cultures. There remains then *R. aurantiaca* which might possibly be connected with *G. macropus*.

The case of *G. biseptatum* is still more desperate. It certainly cannot be connected with *R. penicillata*, or *R. lacerata*, and if we assume it probable or even possible that there is a connection between *G. macropus* and *R. aurantiaca*, there is only left *R. cornuta* to be matched with *G. biseptatum*, and this would imply that *G. conicum* and *G. biseptatum* were forms of the same species, which I presume that few botanists are willing to admit, for excellent anatomical reasons.

The reader has probably in the last few pages been surfeited with if's and or's, and a choice of rather bewildering alternatives. There is only one more point to be suggested in this connection. That is, that the appearance of the spermogonia after sowing the

sporidia of the three Gymnosporangia in question, was in consequence of the presence beforehand, in the leaves, of the mycelium of some Roestelia which was made to develop by the moist condition in which it was placed. I am strongly inclined to favor this view, because in many cases I have from the beginning had my suspicions that the leaves of *Crataegus tomentosa* used might contain the mycelium of a Roestelia.

*R. lacerata* is so common in the region about Boston at just about the date of the maturity of the Gymnosporangia that it has been with great difficulty, at times, that I have procured leaves of *C. tomentosa* which appeared even to the naked eye to be free from the fungus. In some cases pots of the young Crataegus used as control plants, showed a growth of spermogonia without any sowing at all, and it was necessary to reject from the cultures all the pots in consequence of the suspicion which was attached to them. In one case, furthermore, spermogonia appeared on a leaf on the fourth day after sowing, a suspiciously early date, unless one supposes that the mycelium was already in the leaf at the time of sowing. Again, why was it that, with abundance of fresh sporidia of all our common species, in only one instance did spermogonia develop on any other leaves than those of *C. tomentosa*? The same pains were taken in sowing, the same care was exercised during the continuance of the cultures, yet in spite of that, spermogonia were only produced, one case excepted, on *C. tomentosa*, the very plant of all used whose leaves were in some cases doubtful, and produced, too, by three different Gymnosporangia, none of which is the species supposed by Oersted to be connected with *R. lacerata*, our common Roestelia on Crataegus. There is only one thing, viz.: the comparative frequency with which the spermogonia followed sowings of *G. globosum*, that prevents my expressing a strong belief that the results of my cultures indicate that the Roesteliae in question were originally in the leaves used, and did not follow as secondary stages of the Gymnosporangia experimented upon. It must be admitted that the accuracy of Oersted's views with regard to the development of the three Danish species is not so generally acknowledged at the present day as it was a few years ago, and the note of Reess on *R. penicillata*, and Ráthay's recent observations, show that even if Oersted is in general correct in supposing that the Roesteliae are genetically connected with the Gymnosporangia, he has certainly failed to show the connection in the case of given species.

Much may be said on both sides of the question of the relations between the so-called aecidial and final forms, but in this paper I have only considered the two comparatively small genera Roestelia and Gymnosporangium. Much more work remains to be done in this country. In the first place, more extended and accurate knowledge of the distribution of our species is to be desired, and many more cultures must be made. A few suggestions may be made with regard to the latter point. For the purpose of procuring pure spores of the different Gymnosporangia, a difficult matter if we consider how many of the species are parasitic on *J. virginiana*, one might gather specimens in March, in the latitude of Cambridge, and allow them to perfect under cover in the house. *G. macropus* is hardly likely to be connected with *R. botryapites*, which occurs on Amelanchier, because the young knots are formed in summer before the Roestelia makes its appearance. In studying *G. Ellisii* and *G. biseptatum*, which occur on the white cedar, and which are hardly known in the East except where found by Mr. Ellis and myself, it would be well to bear in mind that *R. botryapites* and *R. transformans* are species which have about the same range. It is also an important matter to ascertain the exact date of

the earliest appearance of the spermogonia of the different Roesteliae, and of the appearance of the sporiferous masses of Gymnosporangia in limited regions. This last point I think has not received sufficient attention from European botanists. Unless I am mistaken, I have seen the spermogonia of *R. lacerata* near the Bussey Institution, at a date preceding the maturing of any of the Gymnosporangia of the neighborhood.

Cornu<sup>1</sup> has called attention to the fact that Roesteliae may be made to appear out of season by means of cultures. Another important fact is to ascertain how many of our Roesteliae are perennial. This, at least, appears to be the case with *R. aurantiaca*. If it should be shown that several of our Roesteliae are perennial, a fact true with regard to most of our Gymnosporangia, and to grow in regions remote from species of *Juniperus* and *Cupressus*, then one could not help feeling that any connection between the two genera was probably accidental rather than genetic.

#### EXPLANATION OF PLATES.

##### PLATE I.

Figs. 1-6. *Gymnosporangium macropus* Lk. 1, Sporiferous masses fully expanded; 2, the same in a dry condition, showing the knot or cedar-apple, and the contracted sporiferous masses surrounded by the raised collar at the base; 3 and 4, teleutospores, with a part of their pedicels; 5 and 6, spores producing promycelia and sporidia, 6 showing a promycelium forming at the apex. 1 and 2 natural size, 3-6 magnified 350 diameters.

Figs. 7-11. *Gymnosporangium fuscum* var. *globosum* Farlow. 7, Sporiferous masses expanded; 8, the same contracted, and showing the knot formed; 10 and 11, spores with pedicels; 9, spore producing promycelia. 7 and 8 natural size, 9-11 magnified 350 diameters.

N. B. 9-11 have been drawn on too small a scale, and should be enlarged one fourth in comparing with the spores of other species.

##### PLATE II.

Figs. 13-17. *Gymnosporangium Ellisii* Berk. 13, portion of a distorted branch of *Cupressus thuyoides* with sporiferous masses expanded; 14-17, spores of the same; 17, spore bearing promycelia; 16, anomalous spore forking at the tip. 13 natural size, 14-17 magnified 350 diameters.

Figs. 18-21. *Gymnosporangium biseptatum* Ellis. 18, stem of *Cupressus thuyoides*, bearing expanded sporiferous masses; 19-21, spores of the same; 20 producing promycelia. 18 natural size, 19-21 magnified 350 diameters.

Figs. 22-27. *Gymnosporangium clavipes* C. and P. 22, twig of *Juniperus virginiana*, with sporiferous masses expanded, and distorted, acrose leaves, to be compared with 23 which represents a normal branch; 24, 25, spores with enlarged pedicels; 26, spore which has fallen from pedicel and produced promycelia at both extremities; 27, spore with terminal and lateral promycelia. 22 and 23 natural size, 24-27 magnified 350 diameters.

<sup>1</sup>Bull. Soc. Bot., 1878.















